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ABSTRACT

Faced with a shortage of skilled personnel in certain branches of engineering towards the end of the seventies, the Engineering Industry Training Board (United Kingdom) launched initiatives to recruit 16-year-old girls into technician training and to interest girls following "A" level courses in physics and mathematics in a career of engineering. The Engineering Council, in collaboration with the Equal Opportunities Commission, sponsored 1984 as WISE year (Women into Science and Engineering) legitimizing concern in terms of national economic survival. It was against this background that the Section X Committee of the British Association for the Advancement of Science decided in 1983 that the theme for the Section program in 1985 would be "Women and Science." This volume contains the papers presented in that program, only marginally modified for publication. The first six papers provide evidence of how it is (or has been) with women in science. Recurrent themes are those of social pressures and personal prejudice limiting women's access to science and further constraining the achievement of those who qualify to practice. The remaining five papers take a more theoretical perspective of what is seen as the alienation of most women from science and technology through gender-related constructs of personal identity and of the nature of science. (CW)

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PERSPECTIVES ON GENDER AND SCIENCE

EDITED BY JAN HARDING

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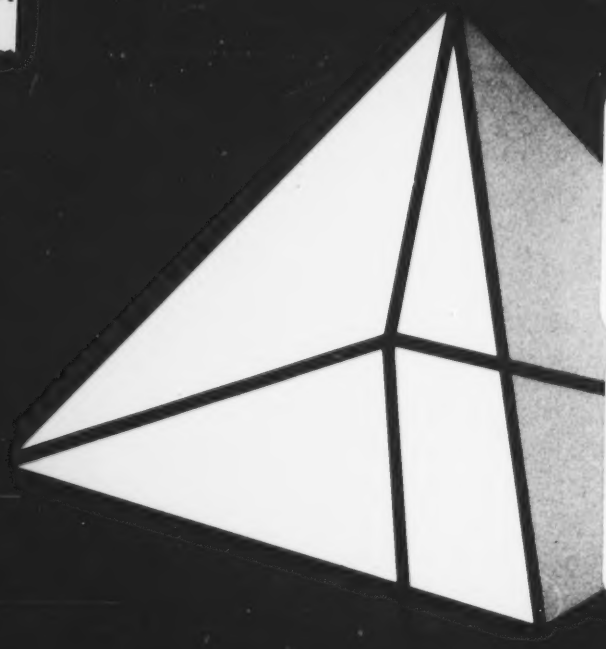

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Perspectives on Gender and Science

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Preface

In January 1984, the Engineering Council and the Equal Opportunities Commission initiated the WISE (Women Into Science and Engineering) campaign. The emphasis was placed on attracting more women and girls into courses and careers in science and engineering. Despite evidence of some initial successes, this campaign will need to be sustained for a period of years in order to overcome the lack of information available to girls and their parents and the pressure on young people to conform to sex-stereotypes in choice of subjects for study.

In parallel with the very practical and pragmatic WISE campaign, there has been increasing realization that profound changes may be needed if the study of science, especially physics, is to be attractive to girls and to more boys, and that the position of women in science deserves serious investigation. Section X of the 1985 meeting of the British Association for the Advancement of Science attempted to examine some of the important issues, and brought together the views of practising women scientists and those of social scientists who have made serious studies of women in science and technology.

Not everyone will agree with all the opinions expressed. Scientists do not have identical views about themselves or the practice of their discipline, nor do observers reach identical conclusions. But it is clear that there is no need for, and no benefit to be obtained from, the imposition of a particular and restricted masculine approach. It is also evident that women have contributed greatly to science and engineering and could contribute much more with greater understanding and encouragement.

Daphne Jackson*
University Of Surrey
January 1986

* Professor Jackson was the first (and is still the only) woman professor of physics in all the universities in the United Kingdom.

Introduction: Perspectives on Gender and Science

Jan Harding

The issue of women and science has gradually assumed prominence over the past decade. Concern for the underachievement of girls and women in science education and in scientific and technological employment has been orchestrated in Britain by three main groups: science educators, feminists and science-based industry. The perspectives of each group, their definitions of 'the problem', the explanations advanced for it and the strategies implied for dealing with it, differ.

Science educators were, perhaps, first in the field. A conference 'Girls and Science Education: Cause for Concern?'[1] was organized at the Centre for Science Education, Chelsea College, University of London, in March 1975, as part of the Girls and Science Education (GaSE) Project, supported there by the Nuffield Foundation. The Association for Science Education, through its sub-committee structure, took up the issue and symposia on girls and science became a regular feature of the annual meetings. Science education, seen as an important aspect of preparation for life, equipping young people to live with confidence in the modern world and to take advantage of employment opportunities, was not reaching girls. There was a growing commitment to seek greater understanding of the alienation of girls from, particularly, the physical sciences and to examine and correct curricula content, materials and teaching-learning approaches for bias against girls.

The feminist movement in the 1970s lacked the cohesion of that in the US, and interactions with science were not an important feature of its concerns. The issue of women and science, from a feminist perspective, appeared first within the radical science movement. Aspects of the problem were presented by Rose and Rose in 1976[2]. Later, a group of women scientists, based in Brighton, published a collection of papers which explored the 'power of science over women's lives'[3].

These illustrate feminist thinking which examines ideological pres-

sures excluding women from scientific achievement and the effects of science and technology on women within a capitalistic and paternalistic society. Change in these terms will occur only as a result of a fundamental shift in ideology and in the structures of society.

Contributions from both feminists and science educators were collected by Alison Kelly in 1981, into an edited volume[4] which provided theoretical perspectives on why girls are under-represented in science education and included a number of research studies carried out in the UK.

Faced with a shortage of skilled personnel in certain branches of engineering towards the end of the seventies, the Engineering Industry Training Board launched initiatives to recruit 16-year-old girls into technician training and to interest girls following 'A' level courses in physics and mathematics in a career in engineering. Here the pressure was on girls already displaying some commitment to science to change their perceptions of themselves in relation to industry, but also of industry itself. Soon after its formation in 1983, the Engineering Council, in collaboration with the Equal Opportunities Commission, sponsored 1984 as WISE year — Women into Science and Engineering — legitmizing concern in terms of national economic survival.

It was against this background that the Section X (General) Committee of the British Association decided in 1983 that the theme for the Section programme in 1985 would be 'Women and Science'. I was honoured to be approached to serve as President of the Section for the year culminating in the annual meeting at Strathclyde University in August 1985 and am grateful to the Association for the opportunity this provided to bring together, in a three-day programme, some of the recent emphases in thinking about the issue. The choice of topics and speakers was, of course, influenced by the orientation of the Section X Committee and its President, but also, in the event, by the availability of people.

This volume contains the papers presented in that programme, only marginally modified for publication. They fall into two parts: the first six provide evidence of how it is (or has been) with women in science (for we could not assume our audiences would be familiar with this). Recurrent themes are those of social pressures and personal prejudice limiting women's access to science and further constraining the achievement of those who qualify to practise.

The remaining five papers take a more theoretical perspective of what is seen as the alienation of most women from science and technology through gender-related constructs of personal identity and of the nature of science. We are invited to see science, yes, as the search

to make sense of the universe and of our place in it, but also as the arena for man's battle with a female nature in which male characteristics of aggression, dominance and control are encouraged. On the other hand science may serve as a safe and reliable haven for those (usually male) who are deprived too soon of emotional support in their upbringing.

Science, appropriated in this way for male needs, is then moulded along lines limited by male experiences, perceptions and ways of processing knowledge. The question posed again and again is '*Would science be different if more women were involved in its creation?*'.

A number of the papers make reference to object relations theory and Nancy Chodorov's use of it to account for the male sense of separation from the world and the female experience of relatedness[5]. Other important sources for the contributors to this volume are Carol Gilligan's criticism of existing models of psychological and moral development for failing to take into account the experiences of women[6] and Evelyn Fox Keller's use of Barbara McClintock's life and work as a vehicle for challenging a range of views of science and scientific method[7]. We were fortunate, indeed, that Evelyn Fox Keller was able to participate, herself, in the programme.

In the first chapter of Part I Anne Walton introduces us to a number of women scientists and shows, through recorded attitudes expressed towards them and by them, that they experienced considerable prejudice against themselves, as women attempting to practise within science, from family and from colleagues. The prejudice may be less overt now, but still exists, as accounts by contemporary women testify. Where women have been granted grudging acknowledgement in the past, it has been in terms of their perceived masculine characteristics. Success in science is promoted by sponsorship and acceptance of one's work by colleagues. It is clear that such support has been denied most women scientists although a few liberal men in influential positions (such as the Braggs and Bernal) have enabled the studies of women. Walton, herself a scientist who has worked in academic and industrial settings, demonstrates that the attraction of science for women lies in the explanatory power of the models generated but also in its instrumental humanitarian potential.

The present involvement of girls and women in science, both in education and employment, is reviewed in chapter 2. Although increases are apparent in engineering, Glynis Breakwell comments that the greater representation of women has by no means kept pace with the overall growth that has occurred in science, engineering and technology. She points out that the increase in personnel forecast by the Butcher Committee Report (of around 70 per cent in electronic

engineering and computer science and 50 per cent in physics) can only be achieved by recruiting much more effectively from among young women. But her studies of attitudes show that while recognizing the potential of new technology to benefit society, girls are much less eager than boys are to seek training in them. Those displaying the 'grab it' syndrome toward new technology express a high degree of self-esteem and they come from homes which possess a computer and where the father works in 'hi-tech'. Far fewer girls report the former and girls' self-esteem, as measured in these studies, is considerably lower than that of boys, again showing the effects of society's assumptions.

Peggy Newton looks more closely at a group of young women recruited through the ETTB's scheme for female engineering technicians in chapter 3. What differentiates them from their female friends in other jobs and their male colleagues? It seems that, initially, this is the ability to see themselves as possessing a mix of characteristics traditionally labelled as masculine or feminine rather than being sex-typed as feminine or as aggressively male. Newton enquires into the antecedents of such androgeny and finds early experiences of toys and of playmates may be important. She found, however, that the context of work and training may be critical for the sustaining of androgeny.

We pursue cultural influences further in chapter 4. Here, Jane Butler Kahle, a leader in biological education in the US, reports on women scientists among racial minority groups. Although some gains have been made, minority women, except for Asians (Filipinos, Chinese, and Japanese) are under-represented in the science and technology work force in the US. The interactions of black women with thier tutors are 'characterized by excessive physical distance, decreased eye contact and fewer offers of guidance and criticism'. Kahle encourages other nations to examine the pressures operating on minority women scientists (or preventing their emergence) in their own social systems. These may be complex and unexpected, as is evidenced by Driver's study in the Midlands of England, which suggests that white, working-class girls may be the most disadvantaged group in science education[8].

The effects of social and family pressures on the women scientist are demonstrated by Irvine and Martin in their study of radio-astronomy (chapter 5). Of those awarded PhDs in this field women were initially as successful as men in terms of publications and citations made of their work. A difference occurred at the time of the first post-doctorial move: for men it was promotion; all but one of the women did so because their husbands moved. What work they then did was a matter of chance.

In chapter 6 Elizabeth Johnson draws on her own experience to show one woman's enjoyment of science and the struggle to continue to work within it while responding to family commitments.

The paper by Helen Weinreich-Haste, which forms chapter 7, serves as an introduction to Part II, raising many of the issues explored in greater depth in subsequent papers. Weinreich-Haste argues that a dualistic ordering of experiences lies behind much of our common sense 'knowledge' and that a gender duality is mapped on to many explanatory metaphors used. She reviews current criticisms of science and scientific method; in particular, she raises the possibility of a rather different science practised by women.

The masculine image of science and especially of physics is blamed by a report of the Institute of Physics for discouraging girls from choosing to study it[9]. Brian Easlea, himself a physicist, explores further the images of science in chapter 8. Using the writings of scientists and science commentators, he shows how frequently sexual metaphors are used in a self-consciously masculine attack by science on nature seen as a mysterious and elusive mistress. He asks 'Must it always be so?' and finds that some men as well as some women have been able to express a passionate love and nurturing of science and nature.

As a science educator involved in teacher education and research, I have been concerned to make sense of the proliferating empirical studies in the field of sex differences in science education. I am indebted to a research student, Michael Sutoris, for introducing me to object relations theory of personal development which seemed to provide the integrative model we were seeking[10]. Since then we have found others using it in a similar way. In chapter 9 I argue that if the science 'object' that an individual is enabled to create through experiences of 'science' matches emotional, psychological or cognitive needs, then he or she is more likely to embrace it and pursue it further. The way science is presented in the early stages of formal education is therefore an important determinant of future choices. Boys and girls are, in general, nurtured to produce in them different emotional characteristics and cognitive styles; science education has, in the past, been presented to match, rather exclusively, the needs of boys.

In chapter 10 Evelyn Fox Keller warns against dichotomizing science into gender opposites. By a clever play on the numbers 1 and 2 she reviews assumptions made about women and science. She draws upon her study of Barbara McClintock (Nobel Laureate in medicine, 1983) to invite us to contemplate counting beyond 2, rather than to accept a singular science for men only or alternative masculine and feminine sciences.

Finally, in chapter 11, the paper by Lynda Birke draws ideas together in summarizing the difficulties facing women in practising science. She reviews explanations put forward to account for the underachievement of women in science and suggests how we must proceed to remove inequalities.

Notes

1 A report of the conference 'Girls and Science Education: Cause for Concern?', March 1975, is available for consultation at the Centre for Educational Studies, Kings College, 552 Kings Road, London, SW10 OUA, of which Chelsea College is now part.

2 COUTURE-CHERKI, M. (1976) 'Women in Physics' and STEHLIN, L. (1976) 'Sciences, women and ideology' in ROSE, H. and ROSE, S. (Eds.) *The Radicalisation of Science*, London, Macmillan.

3 BRIGHTON WOMEN and SCIENCE GROUP (1980) *Alice Through the Microscope: The Power of Science Over Women's Lives*, London, Virago.

4 KELLY, A. (Ed.) (1981) *The Missing Half*, Manchester, Manchester University Press.

5 CHODOROV, N. (1978) *The Reproduction of Mothering*, BERKELEY, C.A., University of California Press.

6 GILLIGAN, C. (1982) *In a Different Voice — Psychological Theory and the Development of Women*, Cambridge, M.A., Harvard University Press.

7 FOX KELLER, E. (1983) *A Feeling for the Organism — The Life and Work of Barbara McClintock*, New York, W.E., Freeman.

8 DRIVER, G. (1980) *Beyond Underachievement*, Commission for Racial Equality. See also DRIVER G. (1977) 'Cultural competence, social power and school achievement: West Indian secondary school pupils in the West Midlands, new community' *Journal of the Community Relations Council*, 4, pp. 353–9.

9 'Girls and Physics', a report by the joint Physics Education Committee of the Royal Society and the Institute of Physics, 1982.

10 HARDING, J. and SUTORIS, M. (1984) 'An object relations account of the differential involvement of boys and girls in science and technology', paper presented at the IPN Symposium 'Interests in Science and Technology', Kiel, West Germany, 2–6 April.

Part I
How it is with Women

1 *Women Scientists: Are They Really Different? An Exploration of the Significance of Attitudes*

Anne Walton

Introduction

For most of my working life I have been a practising scientist. I have worked in industrial and academic laboratories — as a laboratory assistant — and as a consultant. I have also taught chemistry from 'O' level to the supervision of PhD students. But it is only in recent years that I have begun to look seriously beyond my own personal experience — to the role of women in science in a wider context.

To my dismay, it seemed that there had been little improvement since I had embarked on my own career. The dice are *still* so heavily loaded against girls and women choosing a scientific career that I was astonished that so *many* had succeeded, against all the odds, rather than that there were so few.

Many factors deter girls from choosing a scientific career and one of these is undoubtedly the attitudes adopted by parents, teachers, friends and society in general. It was this area which I decided to investigate and my studies so far have indicated that negative attitudes towards women scientists have always existed and still prevail. These attitudes need to be demonstrated and combated because they adversely affect women's careers, role models for girls and boys' expectations of women.

Science is dominated by men, most of its practitioners are men and it is said to have a masculine image. Society does not expect women to become scientists so those that do, know that they are 'stepping out of line'. This, in itself, makes them 'special' in some way because the men, in a male-dominated profession are not, in any sense, rebels. In an attempt to discover whether women scientists have any other character-

istics in common. I have been gathering information about their lives, the way they work, the nature of that work and what they say about themselves.

If one includes both past and present women scientists one finds, superficially at least, a great diversity, particularly in their backgrounds, which range from poor, working-class to rich aristocracy. Some are married, with children, while some are unmarried and childless. However, it is evident that most of them developed habits of independent thought at an early age. Often these seem to have been fostered by parents who, in some cases, were subsequently dismayed when their daughters insisted on following their own inclinations and rejected traditional roles. Perhaps the parents *inadvertently* sowed the seeds of rebellion. Not all of the women scientists had to struggle against adversity as we normally think of it. The privileged ones who could have led idle, comfortable lives, chose not to, but all were quietly confident that what they were doing was *right for them*.

On the whole, I have limited my investigations so far mainly to women working in the physical and applied sciences because they represent a much smaller minority than women in the biological sciences. A consideration of the type of work which these women do may be significant. Interestingly, while most of them began by studying *pure* science and mathematics, as their careers developed, many of them seem to have been drawn to research areas with applications in everyday life, particularly in medicine. Their chosen fields of research, as intellectually tough as any in science, yet had strong humanitarian connotations.

This suggested to me that possibly science as constructed by males might prove to be a 'bad fit' for females. Certainly many girls seem to be ill at ease when confronted by science. Perhaps those women who had forged a career for themselves on the 'inside' of the scientific edifice were, consciously or unconsciously, adjusting and adapting their own function within that framework so as to derive more satisfaction from their work by relating it to a social context.

Attitudes to Women in Science

It seemed to me that the fairest way to discuss attitudes would be to illustrate them using direct quotations by the women's contemporaries wherever possible. These fall into a number of categories each of which exemplifies a particular group of attitudes, although there is considerable overlap.

The idea that there might be innate differences between the intellectual powers of men and women has been bandied about for hundreds, if not thousands, of years. Indeed, a great deal of effort has been put into the search for differences, so far with limited success. At one time, brain size was thought to be an indicator of mental capacity. After the death of the eminent mathematician, Sonya (or Sofia) Kovalevskaia in 1891, her brain, which had been preserved in alcohol, was weighed and the weight compared with that of the brain of the scientist Herman van Helmholtz (Osen 1974). Given the difference in body weight, her brain was proportionately larger. This practice was dropped when the brains of some idiots turned out to be heavier than those of the brilliant! More recently, there has been an interest in the functions of the left and right hemispheres of the brain and attempts have been made to relate these to gender stereotypes. In a book published in 1982 by Richter the question is asked 'Are there then some types of scientific work that women on the whole can do better than men?'. And later 'It may be concluded that women are not lacking in the abilities required for scientific research'. Then in the same paragraph 'The different fields of science offer a wide range of opportunities for people with many different kinds of abilities and so long as they do not expect too much, they offer a life that many find rewarding and enjoyable'. This is hardly encouraging to the budding female scientist.

Some further examples of these attitudes are shown in box 1.

Box 1 — Inherent Differences

> The female ... seldom reach any farther than to a sleight superficial smattering in any deep science. (*The Compleat Midwifes Practice Enlarged*, 1659)
>
> Women have no share in sciences and employments, because that they are not capable thereof. (Poulain de la Barre 1673 (English translation 1677))
>
> Women are cast in too soft a mould, are made of too fine, too delicate a composure to endure the severity of study, the drudgery of contemplation, the fatigue of profound speculation. (*The British Apollo*, 1708)
>
> The principal feature which appears to me to characterize the caucasian race ... is the power that many of its *male* members

> have of advancing the horizon of science. (Bennett, 1870)
>
> There can be no real question that the female mind stands considerably below the male . . . the ready firmness of decision which belongs by nature to the truly masculine mind is very rarely to be met with in the feminine. (Romanes, 1887)
>
> When we come to science we find women are simply nowhere. The feminine mind is quite unscientific . . . (Swinburne 1902)
>
> We must put a stop to this, or we shall have Mary [Somerville] in a straight-jacket one of these days. (Mary Somerville's father about 1800 (Osen, 1974))
>
> The reporter suggested to Irène (Joliot-Curie) that perhaps the career she had chosen would be too punishing for a woman. (Reid, 1978)
>
> Nature herself prescribed to the woman her function as mother and housewife and that laws of nature cannot be ignored . . . without grave damage, which . . . would especially manifest itself in the following generation. (Max Planck, about 1897 (Krafft, 1978))

The notion that intense intellectual activity was damaging to women and particularly to their reproductive function and possible offspring, flourished towards the end of the nineteenth century. Rosenberg's *Beyond Separate Spheres* (Rosenberg 1982) includes an interesting discussion on this issue and its significance for women then entering higher education in the United States.

It follows from the arguments outlined above that if women *do* become scientists they are only fit for work at the lower levels or under the direction of a man, or both. I recently talked to a woman chemist who was employed in industry in the 1920s and 1930s, she said 'I was expected to do all the boring jobs that came into the laboratory, while anything interesting was handed out to one of the men'. Later she said 'I was second in command in my own, now large department, and, as the head enjoyed rather poor health, I often had to run things for weeks or months on end'. When she left in 1935, she says 'they had difficulty in finding my successor, finally paying me the supreme compliment of replacing me by a young man to whom they paid a salary £100 greater than the figure I was receiving after ten years'.

Information on the type of work available to women scientists in America up to 1940 may be found in Rossiter's (1982) *Women Scientists in America* where she points out that promotion to senior positions was virtually confined to the women's colleges unless women were willing to move out of 'mainstream' science into such areas as home economics or nutrition which attracted relatively few men.

Some further examples are given in box 2. There are many more.

Box 2 — What Women can Do

[Women] make excellent assistants, and they could probably do the work of the assay, or city analyst's office, or of an observatory, better than most men. Ladies' names often appear as authors of papers, generally in organic chemistry, or in subjects involving tedious but accurate readings of instruments —. (Swinburne, 1902)

[Caroline Herschel] took care of all the laborious numerical calculations and reductions, all the record keeping, and the other tedious minutiae that required a trained mind but would have consumed too much of Sir William's time. (Osen, 1974)

All [woman's] perceptions of minute details, all her delicate observation of color, of form, of shape, of change, and her capability of patient routine, would be of immense value in the collection of scientific facts. (Professor Maria Mitchell, Vassar, 1876 (*Science*, 1979))

Even Professor A. accords me his sanction when I sew his papers or tie up a sore finger or dust the table etc ... they can't say study spoils me for anything else ... Professor Ordway trusts me to do his work for him ... I am only too happy to do anything for him. (Ellen Swallow (became a founder of the American Home Economics Association) 1870–1873 at MIT (Bernard, 1964))

In the case of Pierre and Marie Curie, Pierre Curie was the creator, who with his genius established new laws of physics. Marie was outstanding for other qualities such as character, exceptional tenacity, precision and patience. (Leprince-Ringuet (Richter, 1982))

> Some teachers encouraged me by saying that [anthropology] would be nice for a woman because there are ... domestic aspects such as cooking and clothing. I did not like such remarks. (Chie Nakane, Tokyo — contemporary (Richter, 1982))

If a woman does manage to succeed in science, against all the odds, the commonest allegation made is that it is because she is collaborating with a man. Because most scientists are men and because in the experimental sciences most people work in a team, the chance of a woman collaborating with a man is very high. Certainly the support of a powerful male sponsor (Rossiter, 1982) can sometimes ensure that a woman is not overlooked, but receives the promotion she deserves. There is no doubt that women scientists have been helped in this way. Mary Fieser, for example, would not have been allowed to practise chemistry at Harvard (Pramer, 1985) had she not been married to Louis Fieser. She became his graduate student and continued as a research associate while other women were not taken on because the professors would not have women in their research teams. Agnes Pockels' work would probably never have been published unless she had received the support of Lord Rayleigh (Giles and Forrester, 1971) who submitted her work for publication. It seems to me that there is nothing unfair or unreasonable in young persons of either sex being helped and encouraged by those who have already achieved success.

Another misleading allegation frequently levelled at successful women scientists is that they are 'exceptional' and therefore that there is no need to bother about any women who are less than outstanding. In a sense, men scientists are 'let off the hook' if they can point to a few women Nobel prize winners and say 'Ah, but *they* are exceptional'. True, but the majority of men practising science are doing no more than useful, competent jobs and why should women be excluded from making similar contributions?

Some quotations related to these themes are given in box 3.

Box 3 — Helped by a Man or 'Exceptional'

> Such work is either done in conjunction with men, or is obviously under their guidance and supervision, and much is made about it out of gallantry. (Swinburne, 1902)

> There existed a vocal group very ready to revive the view that Marie Curie had ridden to success on her husband's coat-tails. (Reid, 1978)

> Errors are notoriously hard to kill, but an error that ascribes to a man what was actually the work of a woman, has more lives than a cat. (Hertha Ayrton, of Marie Curie, approx. 1909 (Reid, 1978))

> All the eminent women scientists have achieved their best work when collaborating with a male colleague. Sir William Ramsay, approx. 1910. (*ibid*)

> There he [her husband] stood waiting while the President conferred the PhD degree ... yet I could not help feeling that he was suggesting something: he was there when it all happened, a woman could never do it alone. W. Muta Maathai, Nairobi, Kenya — contemporary (Richter, 1982)

> If a woman has a special gift — which does not happen often — I do not think it right to refuse her the chance and means of studying ... [but] such a case must always be regarded just as an exception. (Max Planck, approx. 1897 (Krafft, 1978))

> But when a person of the sex which ... must encounter infinitely more difficulties than men ... succeeds nevertheless ... then without doubt she must have the noblest courage, quite extraordinary talents and a superior genius. (Gauss to Sophie Germain, 1807 (Ernest, 1976))

Because of the way that society is organized, I believe that it is still true to say that most women have greater social and domestic responsibilities than men. Experimental scientists cannot work at, or from, home for a lot of the time because they have to be in the laboratory. A family crisis often involves time off from work for the woman of the family rather than the man. It is still assumed that child-rearing and care for the sick and elderly is primarily a woman's job, and many a promising career has been damaged or even abandoned as a result.

Some quotations to illustrate these points are given in box 4. All except the first two are by contemporary women.

Box 4 — Social and Domestic Responsibilities

> A man can always command his time under the plea of business; a woman is not allowed any such excuse. At Chelsea I was

> always supposed to be at home when friends and acquaintances came out to see me. (Mary Somerville, 1780–1872 (Osen, 1974))
>
> I wonder you let Mary waste her time in reading; she never sews more than if she were a man. [She hoped she] would give up her foolish manner of life and make a respectable and useful wife. (Mary Somerville's family (Osen 1974))
>
> I cannot emphasize too much the importance of his [her husband's] emotional support as well as his actual help with the tasks often considered to be 'women's work'. (Marian W. Kies, Bethesda, USA (Richter, 1982))
>
> It was not very easy for me to take care of my child, his father and the house, together with my scientific work. (Liana Bolis, Messina, Sicily (*ibid*))
>
> My parents became seriously ill when I was about to leave [for college]. I had to stay home and care for them. (R. Rajalakshmi, Baroda, India (*ibid*))
>
> But nobody knows the sense of guilt in having to leave the children to be looked after by somebody else for long periods. (Liana Bolis, Messina, Sicily (*ibid*))
>
> I have never neglected any essential aspects of their upbringing, but I do not feel that I have done them any harm by delegating the washing of nappies and their supervision in playgrounds to others. (Tahereh M.Z. Rahmani, Tehran, Iran (*ibid*))

Many married women scientists are strongly supported in their career aspirations by their husbands. Nevertheless, if a conflict of interests arises between husband's and wife's career, it is nearly always the husband's career that wins. Examples abound but the two long quotations in box 5 (below) give a clear picture of a common situation. This was reinforced for me recently on hearing from an ex-student of mine — a woman chemist — who writes 'When my husband was moved to a new job, it was the economically most sensible thing for me to move too — and of course, while he got more money for moving, I would have to make do with anything I could get, so the salary differential just widened at each move'.

If it is difficult to get a job when you move to further your husband's career, it is often even worse if you stop work altogether to

raise children and then try to re-enter your profession. The problems are exemplified in the last quotation in box 5.

Box 5 — Marriage and Husband's Career

> A married woman in science must therefore be very strongly motivated to enable her to overcome all kinds of difficulties. (Inga Fischer-Hjalmars, Stockholm, Sweden — contemporary (Richter, 1982))

> I was under-ranked and under-paid, but 'they' told me I should not be ambitious for myself — only for my husband. I justified my career and my ambitions by being the 'best wife' I could. I did all the household chores and errands and all the entertaining. It seemed right and natural for us to organize our lives around his career ... it did not occur to either of us to make choices based on the opportunities for *both* of us. Twice we chose the best opportunity for him and each time I changed direction, adapted and took a professional step backwards. We left Penn in August because my husband was lured back to Columbia University ... But what of the wife who had relocated again? (Anne Briscoe, 1981 — contemporary American)

> I protected my husband against all the daily annoyances of running a home and rearing four children. During the years when he left us promptly after dinner to return to the laboratory ... or down to his study to work at home, I again took over all the family problems. In this way he was free to devote himself to his work and he was extremely successful, ... when our last child was finally away at school ... I returned to my husband's university. I was given a section of the introductory course to teach and a lab section. After a while I was being shunted in whatever direction current registration or absent personnel indicated need. (Anon — contemporary American (Bernard, 1964))

Many women scientists have had to endure some form of unpleasant sexual innuendo at some time in their lives. Anne Briscoe, an American biochemist, wrote in 1981 'I ignored my stepmother who said if I got a PhD, I would never get a rich husband'. Later in the same article 'At

times it was difficult not to feel the stigma of the spinster status. After I married, it seemed as if my male colleagues had more respect for me.' One infers from this that a clever girl is unattractive and an unmarried one is a failure or a freak. Other examples, some of which are given in box 6 (below) bear out these ideas. The woman scientist, because of her choice of a male-dominated profession is at best 'unfeminine' and at worst, 'masculine'. This attitude, however, does not prevent her from being appraised as a sex object in spite of the fact that such a practice is totally inappropriate in the context of her work. When objections were made to the appointment of the distinguished mathematician, Emmy Noether, on the grounds of her sex, one of her supporters, David Hilbert, retorted 'the Senate is not a bathhouse'.

Box 6 — Masculine, Feminine or Neuter?

Such affectation never was part of her character, which was masculine and just. (Voltaire of Emilie de Breteuil, Marquise du Châtelet (Osen 1974))

What will our soldiers think when they return to the University and find that they are expected to learn at the feet of a woman? (Faculty of the University of Göttingen, of Emmy Noether (Osen, 1974))

She was heavy of build and loud of voice ... no one could contend that the graces had stood by her cradle, but if we in Göttingen often chaffingly referred to her as 'Der Noether', it was also done with a respectful recognition of her power as a creative thinker who seemed to have broken through the barrier of sex. (Hermann Weyl, 1935 (Ernest, 1976))

By choice she did not emphasize her feminine qualities, though her features were strong, she was not unattractive and might have been quite stunning had she taken even a mild interest in clothes. This she did not. There was never lipstick to contrast with her straight black hair, while at the age of thirty-one her dresses showed all the imagination of English blue-stocking adolescents. (Watson (1978), of Rosalind Franklin)

If such a girl studies science and becomes successful, she will find it difficult to act as shy, inferior and apologetic. If she does

> not do so however, she may be accused of behaving 'like a man'. (W. Muta Maathai, Nairobi — contemporary (Richter, 1982))

> Many people on hearing the words 'female mathematician' conjure up an image of a six-foot, grey-haired, tweed suited Oxford clad woman . . . this image, of course, doesn't attract the young woman who is continually being bombarded with messages . . . to be beautiful, 'feminine', and to catch a man. (Professor Martha Smith — contemporary American (Ernest, 1976))

> I wondered how she would look if she took off her glasses and did something novel with her hair. (Watson, (1968), of Rosalind Franklin)

Sonja Kovalevskaia was supposed to be pleased when a man said she was 'the first handsome mathematical lady I have ever seen' and Strindberg called her a 'monstrosity' (Koblitz, 1984). One of her recent biographers referred to her 'masculine energy' (Kennedy, 1983). In a discussion on the technology of thin films, a pioneer in this field, Katharine Blodgett, is described, as 'small, unassuming, bright-eyed and very sharp' (Tucker, 1982). A physics student, talking about her schooldays said, only last year 'All the girls thought I wasn't really a girl. The boys told me I was mad. 'You'll fail your exams' they scoffed. 'Physics is a boy's subject'.' (Couper, 1984).

It has been shown that women frequently over-qualify themselves in order to compensate for the prejudice against their sex. This so-called 'Madame Curie Effect' (Rossiter, 1982) may account for what seems to be fear of competition on the part of male colleagues. Various strategies have been used by men to prevent women becoming dominant and some examples are given in box 7. Presumably it is this fear which accounts for the apparently irrational prejudice which is not uncommon. The second quotation and the three quotations from Richter in box 7 are all by contemporary scientists so the problem has not disappeared.

Other examples exist showing the reluctance of some professors to let women work in the same laboratory as men. Mary Fieser (Pramer, 1985) was made to work 'in the deserted basement of an adjoining building where he [the professor] had no intention of supervising activity'. Otto Hahn says of Lise Meitner (Hahn, 1966) 'with the condition that she was not to enter the laboratories where male students were working, she was permitted to work with me in the wood shop.'

The fact that most European and American universities were

closed to women for so long and that Cambridge University did not award degrees to women until 1948 cannot be justified on rational grounds. Neither can a company justify the statement 'We do not employ women chemists' nor another paying a woman 80 per cent of the man's rate of pay and also having a scale for women which rose much more slowly than that for men. In 1960 the same company offered me a job doing fundamental long-term research on the grounds that there was no chance of me moving into sales or management and so I would remain 'at the bench'. I suppose one could regard this as an example of 'positive discrimination'!

Box 7 — Male Prejudice

Clearly Rosy had to go or be put in her place. The former was obviously preferable because ... it would be very difficult for Maurice to maintain a dominant position. (Watson (1968), of Rosalind Franklin)

My record was good but they did not want to hire a woman. One of them was a third-rate biochemist from a tenth rate medical school. It did not matter that I had a first'rate record from a top drawer university, they preferred men of their own calibre. (Anne Briscoe (1981))

I was mostly left to myself because my colleagues were not accustomed to working with women. [However] when the post of director fell vacant, a man with inferior qualifications to mine was appointed. (Kamala Sohonie, Bombay (Richter, 1982))

Attacks on women colleagues come always from men who are lacking in self-confidence and distinguished achievement. Strong support for women comes from elderly men of distinction. (Chie Nakane, Tokyo (*ibid*))

Mistakes made by women are still *women's* mistakes, while much more serious mistakes made by a man are always the mistakes of a concrete Ivan or Piotr. (Natalie P. Bechtereva, Leningrad (*ibid*))

Women cannot be part of the Institute of France. (M. Amagat, quoted by Eve Curie (Curie, 1939))

> Emil Fischer cherished a strong aversion to women in the laboratories ... this dislike stemmed from his constant worry with a Russian student lest her rather exotic hairstyle result in its catching fire on the bunsen burner. (Krafft (1978))

If I were to pick out one theme which has constantly recurred during my studies on women scientists it would be that of 'invisibility'. By that I mean that their work has been discounted, under-rated, unacknowledged and ignored and they themselves have been belittled. Inevitably this theme has been implicit in much of what has been said already. There is a mass of evidence and, thanks particularly to some recent work, many sources of information are now available. Reference has already been made to *Women Scientists in America* (Rossiter, 1982). Cole's careful analysis (1979) in *Fair Science: Women in the Scientific Community* includes an important chapter on the marginality of women scientists and in *Machina ex Dea* (Rothschild, 1983) the contributors show that women's achievements in technology have been far greater than has generally been supposed. (The book also examines many of the issues surrounding the relationship between women and technology). These works go a long way to redress the balance.

Turning now to some specific examples, Agnes Pockels invented the slide trough for the investigation of surface films on water in 1882. Fortunately, she sent an account of her work to Lord Rayleigh who arranged for it to be published in *Nature* in 1891. An improved version of the Pockels trough became known as the Langmuir trough and is described in Langmuir's paper of 1917. All this is well-documented and accessible (Giles and Forrester, 1971, Derrick, 1982) but I doubt whether one could claim that Pockels was a household word in most surface science circles.

Interestingly, another woman made a major contribution in surface science. She was Katharine Blodgett, born in 1898. After receiving her master's degree in 1918 she went to work at the General Electric Laboratory with Langmuir on the transfer of thin films from water to a solid surface. In his paper of 1919, Langmuir acknowledged Blodgett's contribution saying that she had carried out 'most of the experimental work'. Langmuir-Blodgett films, or LB films as they are now called, have many applications such as the manufacture of anti-glare glass, in integrated optics and lasers and in creating new types of semiconductor (Tucker, 1982; Davis, 1984). But again, Blodgett's name is not a familiar one.

A number of women have made important contributions to the earth sciences but it has been pointed out (Arnold, 1975) that these are

ignored in earth science curriculum materials for American schools. The case of Florence Bascom is cited. She was the first woman to be awarded a PhD by Johns Hopkins and this was the first geology doctorate in the United States (in 1893). She was the first woman Fellow of the Geological Society of America and became a Vice-President in 1930.

Among biologists, two outstanding examples of women whose work has been unappreciated for too long or under-estimated are Barbara McClintock who discovered genetic transposition (Keller, 1983) and Nettie Stevens who played a major rôle in the discovery of chromosomal sex determination (Brush, 1978).

Some quotations illustrating the 'belittlement' theme particularly, are given in box 8.

Box 8 — The Invisible Woman

> You must have been amused at all the furor created by the visit of Madame Curie to this country ... I was quite pleasantly surprised to find that she was quite keen about scientific matters and in an unusually amiable mood ... I felt sorry for the old girl, she was a distinctly pathetic figure. (Boltwood, on Marie Curie's visit to the USA in 1921 (Reid, 1978))

> Perhaps you have seen that Monsieur Ramsay has published some work on the atomic weight of radium. He arrives at exactly the same result as I did and his measurements are less consistent than mine. In spite of that he concludes that his work is the first good work on this subject. (Marie Curie in a letter to Rutherford (*ibid*)

> My husband suggested to Hahn ... that he should at least make some reference, in his lectures and publications, to my criticism of Fermi's experiments. Hahn answered that he did not wish to make me look ridiculous as my assumption ... was really absurd. (Ida Noddack, 1935 (Jungk, 1960))

> When the assistants of the Chemical Institute met her [Lise Meitner] and Hahn they somewhat obviously greeted them with 'Guten Tag, Herr Hahn' (Krafft (1978))

> All a male competitor has to say of a female scientist is that her work is not very original. When such a remark is made to a grants review panel immeasurable harm is done. (Marian W. Kies, USA — contemporary (Richter, 1982))

> When the question is asked 'Who are the top ten in your field?' the woman is not likely to be among those named. (Bernard (1964))

> My former students often write to me appreciatively of my work but they do not find it necessary to cite it in their own. (Anon, — contemporary quoted in Bernard (1964))

The allegation of non-citation is quite common. It is very discouraging and depressing to *know* that you have made a significant contribution in a particular field and then to find that no-one acknowledges it.

A woman chemist wrote to me of her experiences in World War II. 'Although it was so often publicly stated that industry was short of scientists, the Appointments Board were not able to tell me of a single opening for which a woman would be considered. Well-qualified women were not wanted, only quite inexperienced women as hand-maidens.' And 'I was set to serve a former wages clerk . . . He was good enough to show me how to work percentages.'

Another of my correspondents has, I think, managed to identify one aspect of the problem. She says 'There is a real, and usually unspoken, set of attitudes . . . unfortunately not uncommon . . . which come into play when a woman's work, or personality, is at issue. I see it as a *fundamental lack of seriousness*, as if these matters can be dealt with negligently because they are *never of real consequence*' (my emphasis).

I know I used to wonder how old I had to be before I would be taken seriously as a scientist. I hoped it would be 30, but this was not the case, and it seemed to me that I was well past 40 before I felt that I had been accepted as a member of the scientific community.

In an article in the *New Scientist* last year Koblitz comments 'It is sobering to think that the achievements of nineteenth century women scientists had so little impact on the attitude of scientists, educationalists and women themselves that now a century later, we still need special initiatives such as WISE (Women into Science and Engineering) to increase the numbers of women practising science' (Koblitz, 1984).

The Attitudes of Women Scientists

The variety of attitudes which women scientists have expressed about themselves, their work and their colleagues has already been demonstrated to some extent and some others are shown in box 9.

Box 9 — Women Scientists' Own Attitudes

> I objected to myself that it was not the profession of a lady to teach, that she should remain silent, listen and learn, without displaying her own knowledge. That it is above her station to offer a work to the public and that a reputation gained thereby is not ordinarily to her advantage since men always scorn and blame the products of a woman's wit. (Marie Meurdrac, 1666 (Bishop and Deloach, 1970))
>
> In writing these pages, the author was more than once checked in her progress by the apprehension that such an attempt might be considered by some, either as unsuited to the ordinary pursuits of her sex, or ill-justified by her own imperfect knowledge of the subject. (Jane Marcet, *Conversations on Chemistry*, 10th edn. 1825 (Marcet, 1825))
>
> I believe that men and women's scientific aptitudes are exactly the same — a woman of science should renounce worldly obligations. I consider science to be the primordial interest of my life. (Irene Joliot-Curie (Reid, 1978))
>
> I do not like being made conscious of being a woman, and particularly I don't like having to take account of sex in matters concerned with research. (Chie Nakane, Tokyo — contemporary (Richter, 1982))
>
> Two X chromosomes have ... spelled the destiny for endless generations of individuals, irrespective of their natural talents and inclinations. (Rita Levi, Montalcini, Rome — contemporary (*ibid*))

Some women even give men credit for their own ideas. According to Kitteringham (1982), 'Margaret Bryan writing on natural philosophy in 1806, offered herself "merely as a reflector of the intrinsic light of superior genius and erudition ... "'.

Elizabeth Fulhame, however, in her *Essay on Combustion*, published in 1794, went in appropriately, with all guns blazing:

> But censure is perhaps inevitable, for some are so ignorant, that they grow sullen and silent, and are chilled with horror at the sight of anything that bears the resemblance of learning, in whatever shape it may appear; and should the spectre appear in the shape of a woman, the pangs which they suffer are truly dismal. (Rayner-Canham, 1983)

Men of Goodwill

Those of us who did manage to become women scientists owe a great debt to those men who were willing to teach, train and encourage us. Negative attitudes abound, as we have seen, but it is important to acknowledge the existence also of positive ones. Naming names can be invidious but mention must be made in this context of the Braggs and Bernal who encouraged women crystallographers and of the biochemist Gowland Hopkins who took on women research students. Katharine Blodgett worked with Rutherford at the Cavendish Laboratory and was the first woman to be awarded a PhD in Physics from Cambridge (Tucker, 1982). Agnes Pockels' work would have been unknown without Rayleigh's help (Giles and Forrester, 1971) and Weierstrass gave private tuition to Sonja Kovalevskaia (Koblitz, 1983). Gauss was very encouraging to Sophie Germain and he wrote an appreciative letter of thanks to Caroline Herschel on receipt of her edited and up-dated version of Flamsteed's catalogue (Osen, 1974). Evelyn Wilson said of Louis Fieser that 'he was one of the few professors who treated female students as seriously as male students' (Pramer, 1985). Perhaps I should end this necessarily selective section by paying tribute to Professor William Klyne, the first head of the chemistry department at Westfield College, University of London, who declared 'other things being equal' he wanted women on his staff and, as a result, appointed me and one other woman among the founder members of the department in 1961.

Concluding Remarks

There are obvious practical reasons why it is important that the prejudices outlined in this paper should be exposed and combated. More scientists and technologists are needed; industry is increasingly

based on these disciplines. Girls and women need jobs and can fulfil these requirements if they are appropriately trained.

There has been much discussion of late about whether there is such a thing as feminist science. I believe that women do have a different perspective to offer which would enrich science and that they could contribute to the process of change which seems to me to be necessary.

I would like to close with a quotation on the subject of change from the eminent astronomer, Cecilia Payne-Gaposchkin written in 1979, the year of her death, at the age of 79.

> For we spend our lives in trying to overthrow obsolete ideas and to replace them with something that represents Nature better. There is no joy more intense than that of coming upon a fact that cannot be understood in terms of currently accepted ideas ... Only those who have shared this activity can understand the joy of it. Science is a living thing, not a dead dogma. (Haramundanis, 1984)

Appendix

Some women scientists and mathematicians of the past, mentioned in this chapter.

Name	*Dates*	*Discipline(s)*
Emile de Breteuil	1706–1749	Mathematics/theoretical physics
Marie Curie	1867–1934	Chemistry/physics
Rosalind Franklin	1920–1958	Chemistry/crystalography
Sophie Germain	1776–1831	Mathematics/physics
Caroline Herschel	1750–1848	Mathematics/astronomy
Irene Joliot-Curie	1897–1956	Physics
Sonja Kovalevskaia	1850–1891	Mathematics
Jane Marcet	1769–1858	Chemistry
Lise Meitner	1878–1968	Physics
Ida Noddack	1896–1979	Chemistry
Emmy Noether	1882–1935	Mathematics
Mary Somerville	1780–1872	Mathematics/astronomy

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2 *Young Women on Science and the New Technologies*

Glynis M. Breakwell

The purpose of this chapter is to present statistics on the education and employment of women in science and technology and to report a series of recent surveys of the attitudes of young people (14–21 year olds) to new technology. The chief objective is to provide the factual base for subsequent debate.

Patterns of Employment of Men and Women

The most recent figures from the Central Statistical Office (Social Trends 15, 1985) are for 1983 and show 15.5 million men and 10.7 million women to be participating in the civilian labour force. Forty per cent of the labour force is female. Table 1 shows their distribution across the major industries.

Table 1 Employment by industry by sex 1983

	Men	*Women*	*Percentage of Women*
Agriculture, forestry and fisheries	261,000	87,000	25.0
Energy and water supply	576,000	86,000	13.0
Mining and metal manufacturing	659,000	162,000	19.7
Engineering and vehicle manufacturing	2,104,000	546,000	20.6
Construction	897,000	120,000	11.8
Distribution, hotels, catering	1,942,000	2,268,000	53.9
Transport and communications	1,067,000	264,000	19.8
Banking and finance	947,000	890,000	48.4
Other services	2,261,000	3,903,000	63.3

Source Department of the Employment

After the efforts of WISE in 1984, it is hardly necessary to belabour

the point that women are under-represented in the manufacturing industries and over-represented in the service sector. Perhaps more importantly, those who do work in engineering and technology occupy the least skilled and lowest paid jobs. For instance, the EITB reported that, in 1982, of the 53,400 professional engineers in Britain less than 3 per cent were women, while only 2.5 per cent of the 193,000 draughtsmen and technicians were women, and in the craft sections of engineering only 0.36 per cent were women. One year later, a survey of technicians revealed only 2.5 per cent were women and these were employed at the lower levels and possessed a narrow range of skills (28 per cent were laboratory technicians).

It is frequently argued that the position of women in science and engineering is improving. Figures published by the EOC in 1981 showed that in the six years from 1975 the number of women as a percentage of the labour force actually decreased by 4.6 per cent and 3 per cent in instrument engineering and electrical engineering respectively but increased by 0.4 per cent in mechanical engineering, 2.7 per cent in shipbuilding and marine engineering, and 3.8 per cent in professional and scientific services. This has to be set against the backdrop of an overall increase of 19 per cent in the labour force employed in science, engineering and technology over the decade 1971–81 (Census, 1981). Women have gained greater representation in only some areas of the industry and by no means as rapidly as growth in that sector of the economy might predict.

Patterns of Education of Men and Women

The same distribution pattern is evident in higher education. Table 2 shows the percentage of five broad discipline-bands who are female at postgraduate, undergraduate and on other higher educational courses.

Table 2: Percentage of full-time students who are female by discipline and level

	Percentage postgraduate	*Percentage undergraduate*	*Percentage other higher education*
Medical, dental, health	37.8	48.3	83.3
Engineering and technology	8.0	7.4	6.8
Science	21.6	33.7	27.3
Language and literature	44.4	69.6	47.4
Arts	29.4	56.0	57.2

Source: 1984 Education Statistics, HMSO

Apart from the clear gender difference in disciplines studied, one other thing is interesting: women are less likely to go on to postgraduate work except in engineering and technology where the percentage, though very small, is maintained. This means that those women doing such degrees are not disproportionately discouraged from continuing, just the reverse.

These figures represent the latest picture of a gradually changing situation. Over the last fifteen years, for instance, the influx of women into engineering and technology degrees has been 2.25 per cent per half a decade. The rate of change in physics and chemistry has been even slower (1956: physics 6 per cent, chemistry 10 per cent; 1982: physics 12 per cent, chemistry, 25 per cent). This rate of change clearly needs to accelerate if the needs of new technology industries for more science graduates are to be met. The Butcher Committee Report predicted that between 1984–1989 there would be a 56 per cent overall increase in the graduates who would be required (table 3). But, given the drop in the birthrate in the 1960s and the higher entry qualification requirements, the only source of this new generation of information technocrats would be those who would traditionally opt for arts or humanities degrees and these are preponderantly women. The other source, of course, would be retraining on a vast scale, particularly of women wishing to return to work after childrearing.

Table 3 Predicted increase in graduates required in information technology industry 1984–1989 (Butcher Committee Report)

	Percentage Increase
Electronic engineering	71
Maths	66
Computer science	66
Physics	49
Other science/engineering	10

Source Butcher Committee Report

School Subjects at 'O' and 'A' Level

Entry to science, engineering and technology at degree level is very largely dependent upon gaining the correct 'O' and 'A' level passes. It is interesting to examine the statistics on success in GCE/SCE and CSE for signs of changing patterns in the aspirations and expectations of young women. Table 4 shows the percentages of children gaining 'O' level or

CSE grade 1 in a range of subjects. Table 5 gives the same information for 'A' levels.

Table 4 Pupils leaving school in Great Britain with GCE/SCE 'O' (grades A-C) and CSE (grade 1) 1982–83

	Percentage of pupils leaving	
	Male	*Female*
English	34	46
History	14	16
French	11	20
Music, drama	11	17
Maths	34	29
Physics	22	9
Chemistry	16	11
Biology	12	20
Other science	19	3
Geography	20	14
English and maths	26	26
English/maths/science	23	19
All Leavers	460 000	442 000

Source Department of Education and Science

It is evident that the same pattern of imbalance is present at both 'O' and 'A' levels, though it is not so marked as it is at higher levels of education. There seems some scope for encouraging those girls who currently opt for science subjects to continue with them at university or in polytechnics.

Table 5 Pupils leaving school with two or more GCE 'A' levels/ three or more SCE 'H' 1982–83

	Percentage of pupils leaving	
	Male	*Female*
English	28	52
Maths	53	30
Geography	23	18
Science	38	17
Arts/social science	30	49
Mixed	32	33

Source Department of Education and Science

The 'O' level figures reveal that it is not science *per se* which girls shy away from but most especially physics. This is vital because physics

'O' level is now a basic requirement for many science and engineering degree courses. Table 6, because it amalgamates the science subjects as a single category, fudges this issue for the 'A' levels. Table 7 gives older but more instructive information. It can be seen that a greater proportion of the physics 'A' levels are now gained by girls but the rate of change is very slow — slower than for any other science.

Table 6 GCE 'A' level passes: percentage gained by females

	1956	*1980*
Maths	11.3	25.8
Physics	11.9	19.2
Chemistry	15.3	32.7
Computer Science		19.8

These patterns of distribution of women and men across different types of work and areas of education have their own sort of fascination. But, for the psychologist, a single question looms large and this is: why? Why do so few women study science and technology? Why are so few employed in these areas? There are undoubtedly institutional and organizational barriers which function to restrain access or involvement. The barriers are rarely overt since equal opportunities legislation, but in their covert manifestations they can be equally effective. This is particularly true of what has been labelled the 'hidden curriculum'. Children at school are taught traditional gender role expectations by teachers who are often unaware that the way in which they treat a pupil will carry subtle and persuasive messages about what is appropriate for a girl and right for a boy. This, together with the pervasive influence of the mass media, it is argued, accounts for the development of different attitudes towards science and technology which are parallelled by differential subject choices very early at school which will then often restrict later educational and career choices. There is an alternative school of thought, of course, which proposes that there are biological sex differences, genetically pre-programmed, which make boys more effective at maths and girls at linguistics and hence precipitate the subject specialisms. Since there is very little evidence to support this contention and since few would argue that the biological mechanism could operate independently of mediation by environmental influences, it is not a line pursued here.

Much of the explanation of the gender differences with relation to attitudes to science and technology have been speculative; deduction based on the pattern of school subjects studied and employment gained.

The surveys reported below are directly aimed at establishing the attitudinal differences and at mapping the correlates of these differences.

Attitudes to New Technology in a University Sample and a Schools Sample

The Leverhulme Trust is funding a two-year project based at the University of Surrey, directed by Terence Lee and myself, to examine attitudes to new technologies. The research team (Chris Fife-Schaw and John Devereux) has conducted two major surveys up to this point. The first investigated a university sample; the second a sample drawn from a number of schools in the South-East. Since the focus of the survey was attitudes to new technology, particularly at work, it would be fitting to start with a definition of what we mean by new technology. Yet this is no easy task. While in the minds of many it is equated with information technology, it is clearly more than just that, including new biomedical and biochemical technologies too. Part of the task of the work has been to establish just what is considered to be a 'new technology'. The definition is actually transient dependent upon who uses the phrase, the purpose for which it is employed and the context of usage. For current purposes, the definition can be left aside. A subtle picture of what the term means to the respondents in the surveys emanates from the data.

The University Sample

Five hundred and thirty-four students from a single university completed a postal questionnaire which gathered information on attitudes to new technology, political beliefs, orientation to work, educational qualifications and course of study, job aspirations (this study is reported fully in Breakwell, *et al*, in press). Table 7 gives the breakdown by sex and faculty in the sample; this was representative of the university-wide breakdown and 44 per cent of the total number resident at the university.

Table 7 Sex x faculty breakdown of sample

	Faculty			
	Sciences	*Biological sciences*	*Engineering*	*Human studies*
Male	67	34	123	63
Female	34	70	9	134

The scale designed to measure attitudes to new technology comprised five reliable subscales, each an index of a separate component of the attitude:

(i) perceived general benefits of new technology;
(ii) perceived inevitability of technological change;
(iii) the desire to get a technological training;
(iv) concern with so-called 'green issues' (for example, pollution, nuclear catastrophe, etc);
(v) the value of video games.

Though these subscales proved independent when factor analyzed, the pattern of the low level correlations of the scores on each shows that people who expect new technology to bring about general benefits are more likely to regard change as inevitable and to consider training in the new technologies as desirable. In contrast, people concerned with 'green issues' are unlikely to expect new technology to have general benefits. Attitudes to video games are quite distinctive — being negatively related to the perception of general benefits and acceptance of the inevitability of change but positively related to being against technological training and concerned with green issues.

Orientation to work was measured using the Mirels and Garrett (1971) Protestant Work Ethic scale (PWE) which indexes how much intrinsic value the respondent invests in having a job. In the absence of a suitably short conservatism scale, one was constructed and proved reliable. The purpose of measuring PWE and political belief was simple: to assess the relationship between attitudes to new technology and other relevant social beliefs. There proved to be a significant relationship: greater PWE and greater conservatism being associated with a more positive attitude towards the general benefits of new technology, the inevitability of change and the importance of gaining a technological training. Table 8 summarizes the correlation matrix.

Table 8 Correlation between scales

	Inevitability	*Anti training*	*Video games*	*Green issues*	*Conservatism*	*PWE*
General benefits	35	− 32	− 29	− 32	− 32	16
Inevitability of change		− 25	− 17	n.s.	n.s.	09
Anti training			15	21	16	− 22
Video games				16	18	n.s.
Green issues					58	− 21
Conservatism						− 41

Note All correlations are significant at, or above, the 0.05 level except where indicated.

Quite apart from this relatively predictable syndrome of beliefs, the data revealed clear effects for both gender and faculty. Firstly, men believed that there would be greater benefits from new technology than did women ($F = 20.24$, $p < 0.001$). Secondly, men were more favourable to video games ($F = 9.12$, $p < 0.01$). These were the only gender differences. There were no significant effects on any other subscales or on PWE or conservatism.

Pro-training in technology attitudes were related to faculty ($F = 3.72$, $p. < 0.05$) with engineering students being more pro-training and human studies least in favour of it. Human studies faculty students were more concerned with 'green issues' than scientific or technology-based students who did not differ amongst themselves ($F = 7.58$, $p < 0.0001$). For the other subscales there were no faculty effects, nor for the conservatism or PWE scales. It is notable that women were no less likely to favour technological training than men. However, when asked about their job aspirations, only 21.9 per cent of the women in contrast to 65.2 per cent of the men claimed to want high tech jobs (see Breakwell *et al*, 1985).

It is important to add that there were no sex by faculty interactions in dictating attitudes. Thus the girls overall, regardless of faculty, were less convinced of the general benefits of technology than the men. Meanwhile, the engineers, regardless of sex, were more pro-training in technology. This, of course, means that the female engineer must have a strange mixture of beliefs to maintain: dubious of the benefits of technology but convinced of the importance of gaining training in it. The small numbers of women in the engineering faculty should be noted here.

The absence of sex and faculty effects on conservatism and the PWE should not go unremarked. It tends to scotch myths either about women valuing work less or about human studies students being more left-wing.

There is one further finding of interest and that is that there were no changes in attitude across the three years. So, for instance, engineers did not become more pro-training during their time at university, they arrived with an attitude which was maintained (though there is always the caveat that this assertion is based on cross-sectional data). The implication is that the university is not operating to socialize the student into a particular pattern of attitudes. The attitude probably precipitates the choice of faculty rather than arriving as a consequence of it. In terms of the attempts to alter the pattern of female deployment in the arts and sciences, this implies that the structure of attitudes developed at school is vital.

The Schools Sample

This schools survey (the first of several) was conducted in December 1984 in three co-educational schools in the state sector. Fourteen to eighteen-year-olds (fourth to upper sixth) completed a questionnaire, administered in large groups, which covered attitudes to new technology, job aspirations, computer use and literacy, work orientation (PWE), educational background, the technology content of parental jobs, and a measure of self-esteem. The sample comprised 842 boys and 903 girls.

Clearly, with so much data, it is necessary here to be selective (an overview of this data is presented in Breakwell and Fife-Schaw, in press). Firstly, in relation to attitudes, it was found that young people have a much less differentiated attitudinal structure. The only subscale proving reliable indexed how far the pupils felt new technology should be used and training for it acquired. For convenience, it can be called the Grab-It scale.

Basically, regardless of age, girls were significantly less likely to want to Grab-It ($F = 953$, $p. < 0.002$). There was, however, overall a significant effect for year: upper sixth formers being most prone to Grab-It, followed by lower sixth, and fourth; the fifth form were least interested in Grabbing-It ($F = 20.104$, $p \tilde{} 0$). This effect must be in part a product of self-selection in the constitution of the sixth form.

The Grab-It scale scores correlated negatively with self-esteem ($-.18$, $p \tilde{} 0$) and positively with PWE ($.21$, $p \tilde{} 0$). That is to say people wanting to grab technology have a high self-esteem (think well of themselves) and place great intrinsic value upon hard work. This is an important finding since although the sexes did not differ in PWE, the girls had significantly lower self-esteem.

In searching for the origins of a pro-Grab-It attitude, one finding seems especially important. Respondents reported how much high technology was involved in their parents' jobs. The nature of their mothers' jobs proved ineffective as a predictor of attitudes. Their fathers' jobs were predictive. Regardless of sex, those with 'high tech' fathers were more likely to be pro-Grab-It. It is interesting to note from table 9, which gives the means, that those whose father is unemployed are next most desirous of grabbing technology, with those who do not know the content of their father's job least prone to Grab-It.

So far, differences in attitudes have been specified without evidence of their behavioural import. Yet it is clear that the Grab-It attitude is related to school subject choice. Fourth and fifth-formers taking science 'O' levels are significantly more pro-Grab-It. In the sixth-

Table 9 Technology in father's job x Grab-It

	Mean Score on Grab-It Scale
Very high tech	18.76
Medium high tech	19.10
Unsure	21.23
Low tech	19.94
No tech	20.87
Unemployed	19.69

form, those with more science 'O' levels are more pro-Grab-It and those taking science 'A' levels are most pro-Grab-It. This pattern applied equally to girls and boys doing science subjects. It is also clear that Grab-It attitudes are related to amount of computer use and literacy (indexed in terms of number of computer languages known). Again, the pattern holds regardless of sex, though there are massive gender differences in computer home ownership, usage and literacy. Girls are much less likely to live in a home with a computer (39.2 per cent compared with 61.7 per cent of the boys). In terms of literacy, 41.2 per cent of boys claimed to be able to use one language, compared with 21.5 per cent of girls. But the disparity was greater if two languages was the criterion: 15.75 per cent of boys had two, only 1 per cent of girls. Frequency of computer usage shows the same pattern (table 10). The concerning figure is just how many young people never use them.

Table 10 Use of computers in school

	Percentage	
Usage	*Males*	*Females*
Daily	3.7	0.075
Weekly	18.35	8.125
Monthly	5	1.675
Less than monthly	24.2	18.87
Never	47.37	71.22

The Grab-It attitude also related, regardless of sex, to job aspirations. Pro-Grab-It attitudes are associated with a desire for work in technological industries. Yet there is a massive gender difference in job aspirations. The girls are significantly less likely, irrespective of year, to want jobs involving high technology and are more likely to want welfare jobs.

It seems, then, that the gender difference in attitudes towards new technology is established by fourteen years of age and has direct

behavioural correlates. Whether the attitude determines the behaviour or vice versa is not a question that can be answered from this data base. The strong impact of the technology content of fathers' jobs implies that the attitude is fostered in the home at least as much as in the school. There were no significant differences between the schools in pupil attitudes to new technology. Of course, the impact of father's job may be mediated through a number of other channels like the availability of the computer at home because he uses it or like the fact that seeing him at ease with high technology encourages confidence, thus raising self-esteem, and generating interest. There are a host of inferences and hypotheses which can be drawn from the findings. The main purpose here was simply to present some facts and prime the pump for subsequent debate. A more complex analysis of the data is presented in the articles referenced in the text.

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3 *Female Engineers: Femininity Re-Defined?*

Peggy Newton

Introduction

Traditionally the image of engineering has been heavy, dirty and masculine. The field has been seen as the province of men, and except during the war, very few women in Great Britain have become engineers. There has been an assumption that for a woman to succeed in engineering she must either be tough, aggressive and masculine or that she must work in relatively menial jobs requiring manual dexterity and 'nimble fingers'. These images have remained very powerful and have reinforced the notion that engineering was unsuitable for women. Both women and men have seen engineering as a man's world, and until very recently this notion has remained largely undisturbed.

In 1982 only 2.4 per cent of technicians and 3.5 per cent of scientists and technologists in the engineering industry were women (EITB, 1984). Although there have been increases both in the numbers of women technician trainees and in the numbers of women studying engineering at polytechnics and universities, women still remain a rarity in engineering.

However, we are now in a period of transition. Engineering is changing. There is less emphasis on the older heavy type of engineering; now the talk is about computers and chips, printed circuit boards and electronics. At the same time roles of women and men are changing. Both the women's movement and economic changes have altered the traditional division of labour in many families and raised questions about the ways in which we raise our daughters and our sons.

There has been particular concern with increasing the numbers of women in science and technology and in providing women with easier access to these fields. Last year we had WISE (Women Into Science and Engineering) year sponsored by the Equal Opportunities Commission and the Engineering Council. During the year we had a variety of

programmes concerned with attracting women to science and technology. Women engineers became more visible and more newsworthy, and their image changed.

Yet much of the academic research on women in science and technology has reflected these older images. It has focussed primarily on elite groups of women scientists in the United States (Astin, 1969; Bachtold and Werner, 1973; Bernard, 1964; Helson, 1971). Relatively little has been known about women in engineering in the United Kingdom, and most of the information available has dealt with women studying (or preparing to study) engineering at degree level (Weinreich-Haste and Newton, 1983; Wolpe, 1971). But with the advent of special programmes to encourage women, we are learning more about today's women in all levels of technology (Newton, 1981; Newton and Brocklesby, 1982; Breakwell and Weinberger, 1983; Taylor, 1983; Bryant, 1984; Davidson, 1984; EITB, 1984). We are discovering that they are not dramatically different from women in more traditionally feminine fields, nor from their male counterparts in engineering. However there is an important area of difference — in how women in engineering think about gender and define their own femininity and masculinity.

In talking about female engineers, I would like to draw on two lines of research: my own research on a group of young women being trained as technicians as part of a special intiative sponsored by the Engineering Industry Training Board (EITB) and on a recent line of psychological research, which challenges our traditional notions of femininity and masculinity. I would like to begin by summarizing briefly some of the recent psychological research on femininity and masculinity and describe how I included these concepts in my research. I will show how female engineers in my study perceived their own femininity and masculinity and offer comparisons with their male counterparts and with women in traditionally feminine occupations. I will then talk briefly about how young women choose engineering as an occupation and how the process of choice may differ for females and males. Finally I would like to conclude with a brief discussion of some of the implications of my findings for relationships between women and men in engineering and some of the insights offered by psychological research on gender.

Femininity, Masculinity and Androgyny

Until recently most people, including psychologists, have seen femininity and masculinity as polar opposites. Being feminine has implied not being masculine and vice versa. We have expected our daughters to be

friendly, graceful and pleasing; we have cast our sons into a more aggressive, athletic and adventurous mould. We have assumed that having feminine qualities meant that we could not have masculine qualities and that to be female and have masculine qualities was unfeminine. We also assumed that personality did not change and that early childhood dispositions were relatively stable. However, these common-sense notions remained largely untested and unverified. They seemed so obvious as to be unchallengeable.

And yet if we look back into literature and into psychology we find that there are numerous references to people (both women and men) having feminine and masculine characteristics. There are references in the Bible, in Chinese philosophy to the principles of the yang and the yin. We have psychological references to these complementary features of personality in both Freud and Jung. More recently an American psychologist and philosopher, David Bakan (1966), has talked about the need for a healthy personality to have features of both agency and communion.

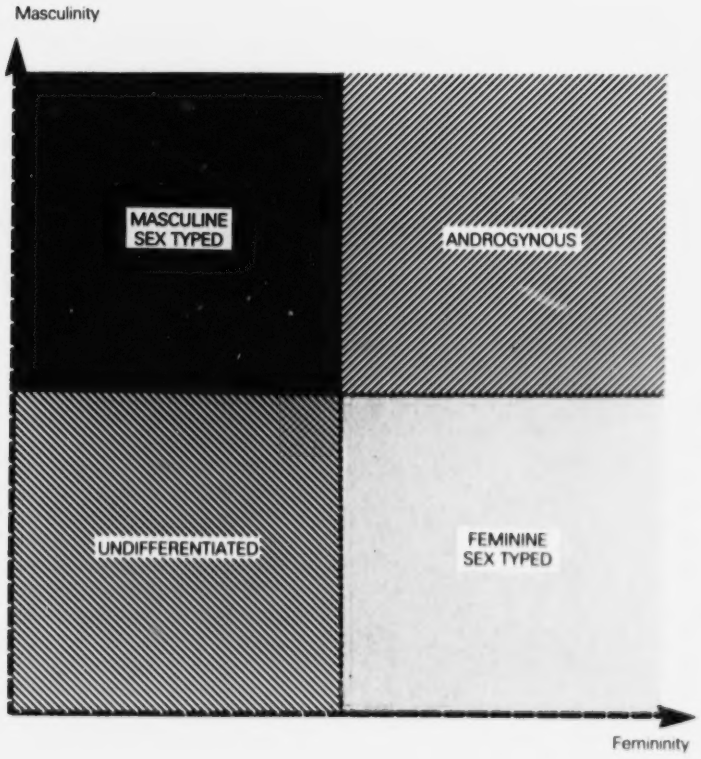
During the 1970s several psychologists challenged our traditional notions of femininity and masculinity (Carlson, 1971; Constantinople, 1973; Block, 1973; Bem, 1974; Spence, Helmreich and Stapp, 1975; Heilbrun, 1976). Working largely on the basis of empirical evidence, they suggested that rather than femininity and masculinity representing opposite ends of a continuum, they were independent and unrelated to each other.

Out of this work came the revival of the notion of androgyny — the idea that people can simultaneously have both feminine and masculine characteristics. It suggested that to understand how people saw gender in relation to their own personality characteristics we needed to ask about the relative balance of their feminine and masculine characteristics.

One of the leading people working in this field of personality research was Sandra Bem. She developed a measure of what we now call 'sex role self concept', known as the Bem Sex Role Inventory (BSRI). Her scale consists of twenty adjectives which describe stereotypically feminine characteristics, twenty which describe stereotypically masculine characteristics and twenty which are neutral in relation to gender. All adjectives are seen as representing socially desirable characteristics in American society. In scoring the measure, there are four possible outcomes — two which represent 'sex typing' — a significant difference in the proportion of feminine and masculine characteristics (feminine sex typing or masculine sex typing) and two of which suggest a relative balance between feminine and masculine characteristics (those who are

relatively high on both scales are classified as 'androgynous'; those who are relatively low on both scales are classified as 'undifferentiated'). (See Figure 1)

Figure 1: Androgyny classification



Bem's early research suggested that psychologically androgynous people had a number of advantages: they were more psychologically flexible and had a wider repertoire of behaviours (Bem, 1974). They were more likely than people who were traditionally sex typed to be comfortable in engaging in behaviour which is usually seen as characteristic of the opposite sex (Bem and Lenney, 1976) There was also evidence suggesting that they had higher self-esteem and were less likely to suffer from depression (Williams, 1978). Her early studies excited an explosion of research using both her measure and other similarly constructed measures of androgyny (Lenney, 1979a and 1979b). Some of these studies confirmed Bem's early findings, suggest-

ing that it was most desirable for women and men to be psychologically androgynous. Other studies questioned her conclusions and suggested that in a male dominated society it was the masculine characteristics which conferred psychological health and stability (Kelly and Worell, 1977).

One stream of research growing out of Bem's research was an interest in how gender related characteristics influenced occupational choice and socialization. Could you say that people in a certain occupation were more likely to be androgynous or sex typed than in another occupation? Did people change over time or in the course of their training in a particular field of work? My own research was designed to look at some of these questions.

My Research

The primary subjects in my research were a group of young women who were being trained as technicians in engineering under a special scholarship scheme run by the Engineering Industry Training Board (Newton, 1981; Newton and Brocklesby, 1982; Newton, 1984; EITB, 1983).[1] They were trained in two types of engineering, in two regions of England: London and the Midlands. Women in London were trained in electronics and electrical engineering, whereas those in the Midlands were trained in light mechanical engineering.

I compared the female trainee engineers (*female engineers*) with two groups: their female school friends (*female friends*) and male trainee engineers (*male engineers*) being trained on the same sites. (The female school friends had either left school at 16 to enter traditionally feminine jobs or had stayed on at school to do 'A' levels.) In London I was also able to compare female engineering trainees and their female school friends with two additional comparison groups: young women undertaking a course of Business Studies which included study of secretarial skills (*business studies*) and young women undertaking a course of Nursery Nursing (*nursery nurses*).

During their first few weeks of training I asked all the subjects participating in the research to complete the Bem Sex Role Inventory (BSRI), a commonly-used measure of psychological androgyny. I compared the scores obtained on both the femininity scales and masculinity scales for people in each group. I also looked at the balance between the two scales for each subject in the study, so that I classified subjects in each group in terms of the four categories: feminine sex typed, masculine sex typed, androgynous or undifferentiated.[2]

Initial Results

Levels of Femininity and Masculinity

My first analysis involved a comparison between groups of relative levels of femininity and masculinity. When I looked at female engineers (regions combined) and compared them with their female friends and with male engineers, I found that very few of the differences were statistically significant.

In the comparison between female engineers and their friends, I found that there was a tendency for the female friends to score somewhat lower on masculinity than the female engineers. Although female friends appear to score somewhat higher on femininity, this difference was not statistically significant. When I compared female engineers with their male counterparts, I found them surprisingly similar. Although female engineers were somehat higher on self perceived femininity and male engineers were slightly higher in self perceived masculinity, these differences were not statistically significant. Both groups saw themselves as having essentially the same instrumental and expressive characteristics, and the differences in their levels of femininity and masculinity were not statistically significant.

*Table 1 Femininity scores and masculinity scores on the Bem sex role inventory for male engineers, female engineers and female friends**

	*Femininity Score**		*Masculinity Score†*	
	Mean	*s.d*	*Mean*	*s.d*
Male engineers (N = 31)	86.10	8.70	97.68	13.41
Female engineers (N = 37)	89.97	13.36	93.03	12.71
Female friends (N = 57)	93.65	13.70	86.83	16.61

Notes: * Differences between male and female engineers are not statistically significant. Female engineers tend to score higher on masculinity than female friends ($t = 1.93$, 92 df, $p < .06$).

† Differences between male and female engineers and between female engineers and female friends are not statistically significant.

* All significance levels reported are for a two tailed test.

When I looked at the four groups of women in London, I found further information about the pattern of scores on the femininity and masculinity scales. Although female engineers had a higher level of masculine or agentic qualities than the other women, their levels of

femininity were not significantly lower than those of their friends or the women in business studies. One of the most interesting groups was the nursery nurses. Although they scored significantly higher on femininity than any other group, they were nearly as high on masculinity as the female engineers. This finding points up the easily forgotten fact that child care requires assertive and instrumental qualities as well as the more obvious feminine and expressive qualities.

*Table 2 Femininity and masculinity scores on the Bem sex role inventory for female engineers, female friends, and young women in business studies and nursery nursing**

	*Femininity Score**		*Masculinity Score*†	
	Mean	*s.d.*	*Mean*	*s.d.*
Female engineers (N = 17)	92.94	15.08	91.41	12.55
Female friends (N = 14)	96.29	10.03	83.36	15.48
Business studies (N = 13)	95.77	8.53	77.01	15.97
Nursery nurses (N = 12)	106.25	9.02	84.08	15.70

Notes * Femininity scores for women in nursery nursing are significantly higher than for women in any other group. [T tests on femininity scores for nursery nurses with each of the groups yield the following values: female engineers ($t = 2.72$, 27 df, $p < .01$); female friends ($t = 2.65$, 24 df, $p < .02$); business studies ($t = 3.02$, 23 df, $p = .006$).]

† Masculinity scores for female engineers are significantly higher than for women in business studies ($t = 2.76$, 28 df, $p < .01$). The differences between female engineers and nursery nurses and female engineers and female friends approach but do not reach statistical significance.

* All significance levels reported are for a two-tailed test.

Androgyny Classification

I looked next at how female engineering trainees compared with their female friends and male engineering trainees in terms of the relative balance of their femininity and masculinity scores. I found that female engineers were significantly more likely to be androgynous than either their friends or than male engineers. Conversely, female engineers were significantly less likely to be feminine sex typed than their friends, whereas male engineers were more likely to be masculine sex typed than either other group. Although there was a slight difference in the proportion of female engineers and their friends who were classified as masculine sex typed (27 per cent of female engineers vs. 25 per cent of

their friends), this difference did not approach statistical significance. Perhaps the most dramatic finding was that 70 per cent of male engineers were classified as masculine sex typed, thus suggesting the importance of stereotypically masculine characteristics to their own self conceptions.

Table 3 Androgyny classification on the Bem sex role inventory for male engineers, female engineers and female friends[1]

	*Androg** N	%	*Masculine*† N	%	*Feminine*‡ N	%	*Undiff* N	%
Male engineers (N = 31)	5	16	22	71	1	3	3	10
Female engineers (N = 37)	16	43	10	27	6	16	5	14
Female friends (N = 57)	12	21	14	25	28	49	3	5

Notes

* Female engineers are significantly more likely to be classified as androgynous than male engineers (Chi squared = 4.61, 1 df, $p < .04$) and than their friends (Chi squared = 4.28, 1 df, $p < .04$)

† Male engineers are significantly morelikely to be classified as masculine sex typed than female engineers (Chi squared = 11.37, 1 df, $p < .001$)

‡ Female engineers were significantly less likely to be feminine sex typed than female friends. (Chi squared = 9.15, 1 df, $p < .003$)

[1] All significance levels reported are for a two-tailed test

When I compared the London female groups I found further substantiation for the overall pattern I had noted. Female engineers

Table 4 Androgyny classification on the Bem sex role inventory for female engineers, female friends and young women in business studies and nursery nursing

	Androg * N	%	*Masculine* N	%	*Feminine*† N	%	*Undiff* N	%
Female engineers (N = 17)	9	53	3	18	3	18	2	12
Female friends (N = 14)	5	36	1	7	7	50	1	7
Business studies (N = 13)	2	15	0	0	9	69	2	15
Nursery nursing (N = 12)	2	17	1	8	8	67	1	8

Notes

* Female engineers are significantly more likely to be classified as androgynous than women in business studies (Fishers exact = .03) and women in nursery nursing (Fishers exact = .05)

† Female engineers are significantly less likely to be classified as feminine sex typed than female friends (Fishers exact = .05), than women in business studies (chi squared = 6.16, 1 df, $p < .02$) and women in nursery nursing (Fishers exact = .01)

[1] Owing to rounding errors, percentages do not always add up to 100%

All significance levels reported are for a two-tailed test

were significantly more likely to be androgynous than any other group. They were also significantly less likely to be feminine sex typed than any other group. Whilst female engineers were slightly more likely to be classified as masculine sex typed than women in the other groups, these differences were not statistically significant.

Interpretation of the Initial Findings

Why does the prospective female engineer see herself as androgynous? Why is she so unlikely to be feminine sex typed? I believe that there are two interrelated sets of factors which shed some light on these findings. The first group of factors is linked with the image of engineering and the procedure for selecting female trainees. It suggests that both women entering engineering and the people who select them find it necessary to balance the masculine image of the field by emphasizing the feminine qualities of female engineers. The second group of factors is concerned with the antecedents of androgyny. It suggests that the precursors of androgyny can be seen in early childhood experience and in the independence these young women felt from their families in making their career choices.

Balancing the Image

Not surprisingly a woman choosing engineering is likely to perceive herself as having masculine qualities. However, the cultural values placed on femininity make it unlikely that the prospective female engineer will wish to see herself as 'unfeminine' and indeed, the decision to do engineering may encourage her to emphasize her feminine as well as her as masculine qualities. Informal conversations with male engineers and training officers who were involved in selecting the women in this sample suggest the selectors did not want girls whom they felt were 'too masculine' and that they preferred girls whom they saw as 'fairly tough' and 'able to cope', but as also retaining feminine qualities.

Therefore, women who choose engineering as a career are most likely to see themselves as having both feminine and masculine characteristics. Past research on androgyny measures (Kelly and Worell, 1977) suggests that they are more likely to be high on both femininity and masculinity scales than to be low on both scales and thus be classified as 'undifferentiated'.

On the basis of the present evidence, it may be suggested that young women entering a traditionally masculine field such as engineering are unusual in that they see themselves as more masculine than their school mates, whereas young women entering a field with a strongly traditional feminine image such as nursery nursing are unusual in that they see themselves as more feminine than their school mates. Although there were no other male groups for comparison, the finding that male engineers were predominantly masculine sex typed fits with the general pattern of results.

The need to consider femininity and masculinity as independent dimensions is seen clearly in the present sample, where (as in Bem's research) the scores have a low negative correlation ($r = -.16$). Previous researchers who have conceptualized femininity and masculinity as polar opposites frequently portrayed the future female scientist or technologist as being less feminine and more masculine than her friends or schoolmates studying arts subjects (Smithers and Collings, 1981; Harding, 1981). Although they appear to have been describing the relatively high degree of masculine traits possessed by these young women, their measures precluded their assessing the levels of feminine traits also possessed by these women. The pattern of results presented here suggests that knowledge of the relative proportions of feminine and masculine characteristics can provide useful information in predicting and explaining occupational choice.

Antecedents of Androgyny

In looking for the origins of androgyny in this sample of female engineers, I found several early indications which suggested they were relatively independent and determined to follow their own interests. They appeared to be less directly influenced by their parents in their career choice than either their schoolfriends or male engineers (Newton, 1981). They also showed early signs of androgyny in their choice of childhood playmates.

Family Influences

Much of the literature on women in non-traditional careers suggests that they come from unusual families. They are more likely to be an only child or the first born child. They are likely to be particularly close to their fathers and share his professional interests (Hennig and Jardim,

1976) or to model after their mother's example of a working woman who successfully combines a career and family life (Angrist and Almquist, 1975). They have often demonstrated their commitment from early on, showing distinctive interests and great perserverance.

In the present study I found little evidence for the patterns of family influence or early commitment previously identified in the literature. When I compared female engineers and their friends, I found relatively few differences. Female engineers were quite likely to be the daughters of engineers, but this was also true of their friends and the control group of male engineers. In my sample, 40 per cent of the female engineers had fathers in engineering, but the figure was almost as high amongst their friends with 34 per cent of this group reporting that their fathers were engineers. The explanation for this finding may lie in how girls perceive their fathers' influence on their career choice and when in the process of career choice the father's attitudes are expressed or perceived to be expressed. (As noted below, the parallel process for boys appears to operate quite differently.)

Previous data on this sample suggests that fathers were unlikely to suggest engineering as a possible career choice to their daughters (Newton, 1981); however, they were usually highly supportive and encouraging to their daughters after the initial decision had been made (Newton and Brocklesby, 1982). This interpretation is in line with Wolpe's study (1971) of graduate engineers. She found that 59 per cent of her sample had fathers or brothers in engineering; however, they frequently did not see their family as influential in their career decision. It appears that fathers may serve as important exemplars of engineers and that they are often described as being positive about their daughters' interest in engineering (Weinreich-Haste and Newton, 1983); however, they are not seen as directly influencing career choice. Their influence is perceived indirectly and their role in providing a model of an engineer is often not recognized.

This pattern of influence contrasts sharply with the parental influences reported by the male engineers and the female groups in traditional roles (female friends, women in business studies and women in nursery nursing). Both males and females in these groups saw their parents and family friends as directly and highly influential in their career choice, whereas female engineers saw teachers and the media as being more important in their choice of engineering and were more likely than subjects in any other group to say that no one influenced them in their career choice (Newton, 1981; Newton and Brocklesby, 1982).

Unlike previous research on women in non-traditional roles (Hen-

nig and Jardim, 1976), there was no tendency for female engineers in the present study to be first or only children. In fact, both female engineers and their friends were most likely to be second or third children. There was no difference in the numbers of brothers and sisters they had or in the pattern of their families. Mothers in both groups were usually in paid employment, and there was no difference in their occupations or their pattern of working. The only family difference I could find was that female engineers were more likely to have fathers who were in very demanding professional jobs — the Registrar General's Class 1, with 19 per cent of the sample having fathers who fell into this group. This finding confirms the results of several other studies in suggesting that professional families are more likely to support a non-traditional career choice (Epstein, 1968; Standley and Soule, 1974; Helson, 1971; Wolpe, 1971).

Childhood Playmates and Toys

In exploring my female subjects' recollections of early childhood experience, I found some evidence for the future female engineers subsequent androgyny. Female engineers were somewhat more likely than their friends to have played with both girls and boys in their childhood and less likely than the other groups to have had only girls as playmates. They were significantly more likely to have played with unconventional ('boys') toys in their childhood than all other groups (Newton, 1984).

This link between childhood activities and achievement in non-traditional fields has also been reported by Connor and Serbin (1977) and by Standley and Soule (1974). Coupled with the information on their subject choices and subject preferences at school, the picture is beginning to emerge of the prospective female engineer as being somewhat more willing than her friends to cross usual sex role boundaries. She appears to enjoy activities that are often labelled as masculine and is more likely to spend time in mixed groups or groups which are predominantly male than to associate only with other girls. At school she saw mathematics as her favourite school subject; she was more likely than her schoolfriends to have studied physics and she may have studied (or attempted to study) non-traditional options, such as technical drawing, engineering science or metalwork (Newton, 1981; Newton, 1984).

These findings fit well with contemporary research on psychological androgyny. According to Bem's recent theoretical formulations of

'gender schema' theory (1981, 1983 and 1985), androgynous people are more likely to be relatively unconcerned about issues of gender and to processs information less in terms of gender attributes. They may be less involved in sex role stereotypes and see people more in terms of their psychological characteristics with relatively little reference to current cultural definitions of femininity and masculinity.

In line with Spence and Helmreich (1979) I found that their psychological androgyny appeared to bear little relationship to their attitudes towards sex roles. Female engineers in my research were no more feminist than their friends and they changed relatively little in their attitudes towards women's roles during the first two years of their training. Whilst they believed strongly in equal rights at work, the majority of them defended a traditional division of labour in the home. Although they became somewhat more feminist during their training the changes were not dramatic and few members of the group labelled themselves as feminists. However, female engineers continued to represent a sharp contrast with their male colleagues, and the differences between the two groups appear to have been accentuated during the course of their training. The origins of these differences appear to stem from several factors.

Differences between Female and Male Engineers

The process of choosing engineering and its timing differ for females and males, and these differences must be viewed in relation to conventional gender role expectations. The boy who chooses engineering at a relatively early age is seen as following natural interests and talents. He is often encouraged in a single minded pursuit of engineering-related hobbies, and his narrow interests are seen as both natural and appropriate. His choice is seen as congruent with his developing masculinity. In contrast, the girl choosing engineering is seen as defying gender role expectations. Both Rossi (1965) and Roberts (1964) have suggested that girls view engineering much more negatively than other scientific careers and that they see the field as extremely unfeminine. Rossi suggests that girls expect little parental support for the choice of engineering as a career, especially from their mothers, and that they assume that they will meet with resentment from future male colleagues. Unlike other scientific careers, many women see engineering as a job requiring skills and characteristics that women do not possess.

In explaining the choice of a career in science or engineering, previous researchers have looked for early dedication and commitment to the field (Astin, 1969; Davis, 1975; Burks, 1975). Women in scientific

fields have frequently described how their talents have been apparent from an early age and how they have been encouraged by their parents to commit themselves to a demanding career (Kundsin, 1973). The literature on male engineers at graduate level suggests that they choose engineering unusually early, even in comparison with other male peers and that they are often relatively narrow in their interests (Johnson, 1975; Ott, 1978).

But unlike women scientists and male engineers, women engineers appear to make their career choice relatively late in their school or university careers (Wolpe, 1971; Johnson, 1975; Ott, 1978; Bryant, 1984). They appear to have a wider range of interests than their male counterparts and often choose engineering for different reasons.

This general pattern of findings was confirmed in the present sample of female technicians with the majority of them (65 per cent) deciding on engineering during the last year of school. Many of the young women considered engineering for the first time when they heard about the EITB's special programme of scholarships. Previous research on the process of their career choice suggests that one of the primary reasons for their delayed choice was that they were not aware that engineering was a possible career for women (Newton, 1981).

It should be noted that the female engineers were not alone in this pattern of making their career decisions during their final year at school. The timing of their choice was similar to that of their female friends who left school at the same time and also to the group of girls who studied business studies. This pattern of choice contrasted with the group of boys in engineering and with the nursery nurses.

These findings may be interpreted in several ways. The most common interpretation would rest on the comparison between girls and boys. It is easy to claim that most girls are not really serious about their careers and lack commitment to them. However, several writers have suggested that girls may realistically appraise their possibilities and see their future careers as offering them fewer certain prospects and rewards (Angrist and Almquist, 1975; Laws, 1978). Their career aspirations are conditioned by the possibilities open to them and they are aware of potential discrimination and also of the practical difficulties of combining paid employment and family life. Angrist and Almquist (1975) have suggested that for women career commitment is necessarily contingent upon other considerations (or potential considerations) in their lives and that women need to be relatively certain of their success in a field before committing themselves to it.

The pattern of findings also suggests that early career choice and commitment is more likely when it accords with conventional gender

role expectations and when there is an opportunity to become personally involved in the career before making the choice. Boys who choose engineering will have heard about engineering as a possible career at an early age and will often have pursued hobbies which have allowed them to confirm that this is a field for which they have some aptitude and interest. In a similar way girls who enter nursery nursing will have had an opportunity to gain experience with young children and to learn about their own skills. In both cases they will have had a chance to 'try out' a future occupation. The parallel process is unlikely to occur in non-traditional fields, because certain occupations are almost automatically ruled out because of their usual sex typing. This lack of experience with relevant hobbies often makes it difficult for girls to discover whether they will enjoy engineering; it also means that young women candidates for engineering courses may present a different profile of interests and perceived abilities than the typical male candidate. They usually share an equal commitment to engineering, but the process of choice will often have been quite different.

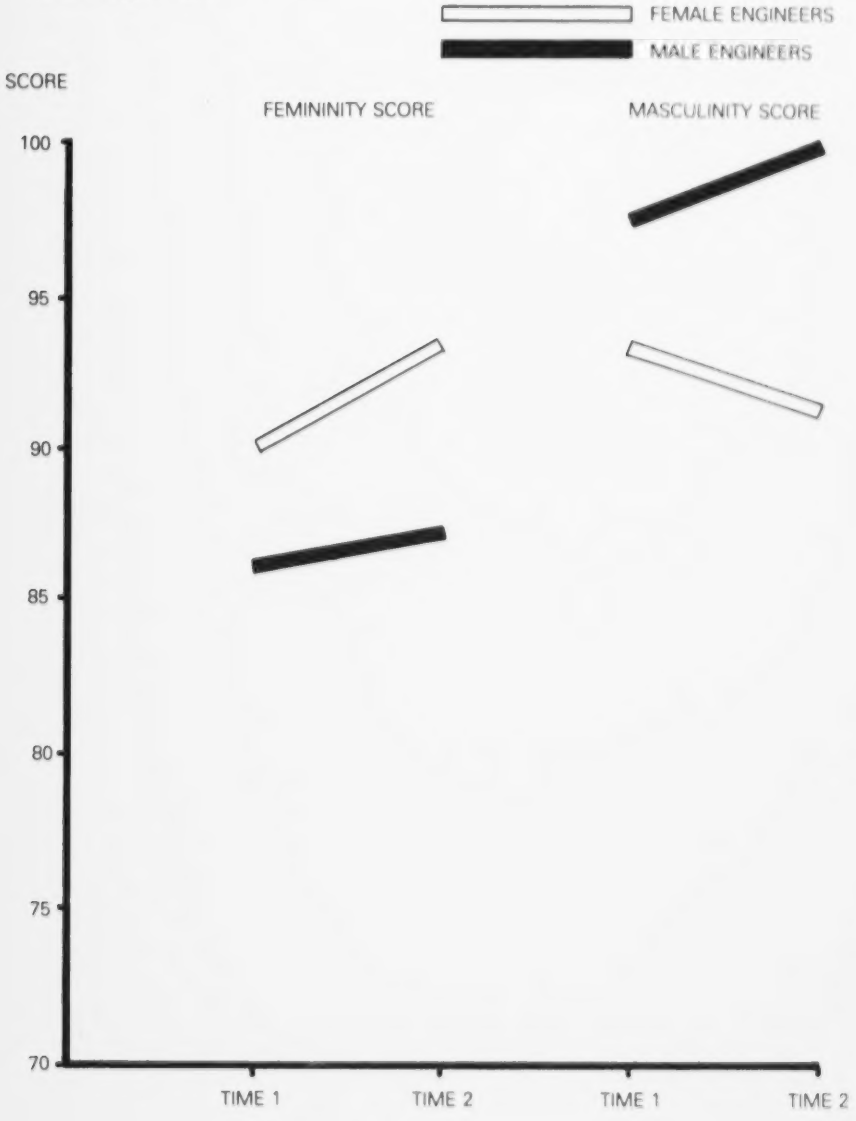
Unfortunately a follow-up of subjects in the current study after their first two years of training suggests that the experience of working in engineering appears to accentuate existing differences between female and male engineers. (See figure 2) After their first two years of training both female engineers and male engineers saw themselves as more traditionally stereotyped than when they began training. These findings and their implications are discussed briefly below.

Changes in Perceived Femininity and Masculinity

When they began training the differences in the levels of perceived femininity and masculinity reported by female engineers and male engineers were not statistically significant. However, after two years of working in engineering, self perceptions tended to diverge, and differences between females and males were significant. Female engineers saw themselves as having more stereotypically feminine characteristics than male engineers, and conversely male engineers saw themselves as having more stereotypically masculine characteristics than female engineers.

There were some differences between the two regions. However, the largest changes were observed in both female and male engineers working in mechanical engineering in the Midlands. These findings suggest that this environment may have served to polarize sex roles and reaffirm traditional norms. It would appear that the strongly masculine

Figure 2: Changes in feminity and masculinity by female and male engineers.



Differences between female and male engineers on femininity and masculinity are not statistically significant at time 1. These differences are highly significant at time 2. (Femininity at time 2 : t = 2.07, 66 df, p< .04, 2 tailed test; Masculinity at time 2 : t = 2.40, 66 df, p< .02, 2 tailed test.)

workplace and predominance of males encouraged both sexes to see themselves and each other primarily in terms of stereotypes.

A theoretical explanation of this phenomenon has been offered by Kanter (1977a and 1977b) who suggests that when either sex is in a serious minority, sex role boundaries will be emphasized and heightened. The woman or man who is a member of the minority group and is viewed as a token is likely to face added stress not experienced by majority group members. The female engineer is forced to try harder and prove her competence in ways that her male colleagues are not (Newton and Brocklesby, 1982). Her position is a source of added and continuing stress, and she is far more likely to leave engineering because of these extra pressures than she is to rear a family (Davidson, 1984). This situation is not confined to engineering but occurs in virtually all occupations in which there is a serious imbalance in the proportion of women and men (Schreiber, 1982).

Implications of the Research

Both as a feminist and a psychologist, I believe that there is a future for women in engineering. Women are becoming more visible in engineering, and they are successful (EITB, 1983 and 1984). There are steady increases in the numbers of women entering engineering at graduate level, and the number of initiatives to encourage women is growing (Bullivant, 1983; Bullivant and Onions, 1983; Jackson, 1984).

These are all hopeful signs. However, female engineers remain pioneers and continue to represent a small minority of the skilled and professional workforce in engineering. Schoolgirls are still 'put off' by engineering's masculine image, and their parents, teachers and peers continue to see careers in highly stereotypical terms (Weinreich-Haste and Newton, 1983; Kelly, Whyte and Smail, 1984). This situation is exacerbated by the British educational system which requires pupils to specialize at age 13 or 14, an age when both sexes hold rigid views of appropriate sex roles (Ullian, 1976).

As both engineering and sex roles are changing, there is a need to confront these changes with flexibility and imagination. The newer image of engineering is more attractive to both sexes. But without careful thought, the old highly masculine image of engineering will be preserved. As there is growing concern about increasing the number of talented entrants to engineering and technology, there is a need for an image of technology which is less bound by gender.

The present research challenges the popular conception of the

female engineer as a very masculine person and suggests that she sees herself as having both feminine and masculine characteristics. She probably enjoys mathematics and has shown some aptitude for it. As a child she may have played with unconventional toys and have socialized with both girls and boys. She is committed to her work, but hers may be a growing commitment, not the realization of a childhood ambition. She maintains feminine interests but may see her role in terms of improving social conditions through contributions to technology, rather than working directly with people.

Bem (1978) suggests that her theory of androgyny carries with it the seeds of its own destruction and that our goal should be to transcend gender and to see people in terms of their real characteristics. Her vision offers an idealistic view of the future. However, as recent feminist theory clearly demonstrates, female and male experience is profoundly different (Chodorow, 1978; Gilligan, 1982) and there is a serious danger in ignoring and undervaluing feminine characteristics. Female scientists and engineers are different from their male colleagues, and they bring a different perspective to their work.

Research by Ailsa Swarbrick on women returning to engineering reinforces this theme. Swarbrick (1982 and 1984) found that women in her sample questioned the values they had previously accepted and looked for different types of jobs when they returned to engineering. Frequently these jobs were ones which would enable them to improve social conditions or preserve the environment. They were more inclined to evaluate technology in a particular context, rather than to endorse it as an abstract positive value.

My research began with questions about what would happen to women working in technology and how they might change. Increasingly my concern has been with questions about how technology might change if there were more women present and their position were both more powerful and less marginal. The title of my paper suggests that women in engineering had new definitions of gender. But we must also ask whether technology can be redefined to embrace a wider diversity of people and values.

Notes

1 The research described was funded by the Social Science Research Council, the Engineering Industry Training Board and the Equal Opportunities Commission.

2 Subjects were classified using the t ratio method, described by Bem and

Watson (1976). Subjects with an individual t ratio > 2.25 between their femininity and masculinity scores were classified as sex typed. Weighted group medians for females and males were used to assign subjects to the androgynous and undifferentiated categories.

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4 *From One Minority to Another*

Jane Butler Kahle

Introduction

> Labor market indicators, such as labor force participation and science and engineering employment rate, for women scientists and engineers vary in a fairly narrow range by race ... Differences by race are less than the differences by sex within all racial groups. Hence, it appears that gender is a more significant factor than race in the labor market behavior of minority females in science/engineering fields. (NSF, 1984, p. viii).

The place of minority women in science and engineering has been called a double bind, while the scientific education of minority women has been dubbed a double dilemma (Kahle, 1982). Both titles reflect the dual condition of women who are also members of a minority group. Regardless of country and irrespective of type of minority group (ethnic, racial, or religious), women, who are also minorities, have lower status and fewer opportunities for careers in scientific or technological fields.

Until very recently, one could not even chart their progress; for they were invisible in the data collected. Although data on the entry and participation rates of women and of minorities have been available for the past ten years in the US, only within the last two-three years have those data been broken down by both gender and racial/ethnic group. Elsewhere, there is simply no information. Yet, there are minority women in every nation: for example, Muslim women in the Philippines, Algerians in France, Moluccans in the Netherlands, Thais in Saudi Arabia, Indians, Pakistanis and West Indians in Great Britain, Turks in West Germany and Jews in Russia. As Lewis (in Stein, 1985) states, 'Minority women come from a variety of backgrounds. They represent

all continents, come in all colors, shapes, and sizes, and speak a multitude of languages' (p. 366). Yet, all minority women must confront the stereotypes of their group and of their gender as they seek entrance to and success in scientific and engineering careers.

Minority Women in the US

Since the US has confronted the double dilemma of minority women longer than most countries, I will use our experience and examples as I discuss the barriers to moving from one minority to another. The situation in the US is widely applicable since it has a variety of minority groups, some of which are analogous to those found in other countries. Furthermore, a range of stages of integration into scientific professions is found in the US, which represent conditions in various nations. Within the US, the following groups are commonly identified.

Blacks, which may include both Hispanics and non-Hispanics

Hispanics, which may include both black and non-black people from Cuba, Mexico, Haiti, Puerto Rico, and other Central and South American Countries

White, which includes all religious and ethnic groups not of Spanish origin

Asian-Pacific Islander, which includes Chinese, Japanese, Korean, Filipino, and Vietnamese as well as Fijian, Tahitian, Hawaiian, Eskimo, etc.

Native American, which includes all Indian nationalities on the continental US

Within those broad groups, members may be native or foreign born. In fact, it would be easy to argue that differences within the groups are as great, or as real, as differences between the groups. Only recently have data been available across these groups. However, depending on group size, data may or may not be available by gender within a group.

In the past, diverse minority women, from the highly-paid Asian scientist to the entry-level Hispanic technician, have been discussed as a monolithic group. This paper will present data and draw analyses for distinct groups of minority girls and women. Yet, even then, incongruities occur within each designated group: for example, an

upper-middle-class Cuban girl residing in Miami will have different opportunities and problems than a lower-class Chicano girl living in Los Angeles; yet, both are classified as Hispanic. Lewis describes the differences among minority women in the following way.

> The fact that American women constitute a population varied in race, class, educational status, economic condition, cultural background, legal status, and so forth means that they are differentially affected by individual, group, institutional, and state attitudes and behavior. When a minority woman is denied a promotion, it is difficult to determine whether that denial stems from racial, cultural, sexual, or regional biases. It is also difficult to determine which of these biases is more fundamental to her problem than the others. By the same token, it is difficult to determine whether textbook stereotypes of females are more damaging to the image of minority women than are textbook stereotypes of minorities. All the women are not white and all the minorities are not male: some of both groups are minority women who are discriminated against because they are members of both categories . . . Both are ascribed characteristics; the acquired characteristic of economic status, educational status, and so forth are related to the ascribed characteristics because being born female and nonwhite adds additional restrictions on social mobility in American society. (Lewis in Stein, 1985, p. 373).

Although within-group differences are pronounced and between-group differences are great, Lewis asserts that *all* minority women must combat dual negative stereotypes and confront lower social mobility.

Educational Mobility

In U.S. research and literature, one still finds the suggestion that 'all the women are white, all the blacks are men, but some of us are brave' (Hull, Scott and Smith, 1982). Much of the money to improve educational equity has been geared to one of two generic groups: women or minorities. Minority women, therefore, may be overlooked as a special population. Yet women within each minority group must overcome obstacles to them as women and obstacles to them as minorities. As they move into places of status and stature in engineering and scientific professions, they move from being a member of a minority group (Black, Indian, Asian) in society to being a member of a minority group

(women) in science. Two places provide key opportunities for minority women to move from one minority to another: first, in college and university classrooms, and second, in the workplace. Since education has historically been the avenue to upward mobility, let's first examine its importance in moving women from one minority to another.

Secondary School

Some researchers contend that secondary schools may be the critical educational component in encouraging or discouraging women, including minority women, to enter scientific careers. For example, in discussing potential scientists and engineers in the United States, Berryman (1983) analyzes how people enter the technological and scientific pool and why they leave it; she refers to this process as 'the pipeline' to scientific and technological careers. She notes that because fewer girls than boys elect advanced science and mathematics courses in high school, proportionately fewer girls than boys enter the pipeline. Berryman suggests that 'the key for women is pre-high school interests, . . . [which] triggers an educational sequence that ultimately results in underrepresentation among quantitative doctorates' (p. 84). She considers the effect of attitudes toward science on enrollments, attributing the decline in students' positive attitudes toward science between grade 3 (50 per cent) and grade 8 (20 per cent) to the fact that the overwhelming majority of elementary teachers are women, who are themselves less apt to like science or feel competent in it.[1] Berryman maintains that the high school tradition of offering advanced maths courses as electives interacts with girls' lower interest in maths to close doors to technological and scientific careers. In the United States, fewer than half as many women as men indicate they intend to select a quantitative college major, either as high school seniors or as college freshmen (NSF, 1984). Moreover, this disparity has been stable over almost a decade. As Berryman (1983) succinctly states, 'Removing choice during high school would preserve it after high school' (p. 84).

Internationally, similar results have been found. In the United Kingdom, Jan Harding (1983) has been an advocate of removing choice. She maintains that the early selection of academic track in comprehensive schools, particularly, tends to limit the number of girls selecting physics and chemistry curricula. Alison Kelly's (1984) work with Girls in Science and Technology (GIST) also addresses the barrier of early commitment to one academic program.

Retention of minority girls in the pipeline is crucial. Data, describ-

ing the percentage of 1980 sophomores who left high school before graduation, indicate that only native American girls drop out at a higher rate than their male counterparts (31.8 per cent girls; 27.2 per cent boys). Hispanic boys and girls leave secondary school in equal proportions, while in other groups more boys than girls leave (ACE, 1984). Although more minority girls, compared with boys, may stay in school, few minority students enroll in advanced science and mathematics classes. Marrett's (1982) study of over 9000 science students indicates that white students are more likely to be in science courses than black students. Of physics' enrollees, for example, white males composed almost one-half, and white females nearly one-quarter, while black boys and girls each represented only one-eighth of the total student population. She concludes that 'for both science and mathematics the number of minority females in advanced courses was about three-fourths of the expected count' (*ibid*, p. 39). However, black males are more underrepresented than black females in both science and mathematics courses.

Since the opportunity to study advanced mathematics and physical science courses is only available to students who remain in school, retention rates for various minorities are important. In every nation, minority students (with the exception of Asians in the US)[2] leave secondary school at a higher rate than their majority counterparts. Overall the following retention rates for minority boys and girls in the US were found in 1982:

White	81%
Native American	60%
Blacks	47%
Hispanics	41%

However, minority students who remain in school go to college at higher rates than white students do. In proportion to their number in the total pool, 62 per cent of white, high school graduates enroll in college, compared with 65 per cent of blacks, 72 per cent of Hispanics, 100 per cent of Asians, and 188 per cent native Americans (ACE, 1984).[3] However, the 72 per cent Hispanic college enrollment rate masks the fact that 59 per cent of Hispanic students are lost to the pipeline before making a decision about college.

College/University

A recent report from the American Council on Education (*ibid*) supplies basic enrollment information by minority groups, including both males

and females. Since 1978, minority enrollments have levelled, showing only mildest gains against population share. Between 1976 and 1978, minority enrollments increased from 15.4 per cent to 16.5 per cent of all students at two and four-year colleges.

Hispanics, who represented 7.5 per cent of the 18 to 24-year old population cohort represented 5.7 per cent of those enrolled in two-year institutions, 2.9 per cent of those in four-year institutions, and 3.9 per cent of all post-secondary enrollments. Asian-Americans, on the other hand, represented 1.5 per cent of the 18 to 24-year-old populations and 2.4 per cent of the total college population: 2.1 per cent in two-year institutions and 2.8 per cent in four-year institutions.

Both Hispanics and Asians showed gains in college enrollments, but Asians had higher gains. Blacks, however, experienced enrollment decreases in both two- and four-year institutions. Blacks represented 13.0 per cent of the 18 to 24-year-old US population in 1980, but only 9.2 per cent of the college population (10.4 per cent in two-year institution, and 8.4 per cent in four-year institutions).

Obviously, the legislation in the US of the sixties and seventies, designed to provide equal access, has not worked equally well for all minority groups. Native Americans, with a 0.7 per cent share of all higher education enrollments, are represented at about the same rate as their overall population share of 0.6 per cent. They are, however, disproportionately represented in the two-year institutions, with 1.0 per cent of total enrollments (*ibid*, p. 5).

Figures for degrees conferred also point out differences among minority groups. For example, between 1976 and 1981 blacks declined in both absolute numbers and in percentage of degrees earned, while members of all other minority groups registered increases. Asian-Pacific Americans had an astonishing 63.2 per cent increase in number of baccalaureate degrees earned. Although both Hispanics and native Americans earned more degrees in 1981 than they did in 1976, they were still underrepresented compared to their proportion of the college age population. During this same period, black women increased their share of both BS and PhD degrees. In 1980–81, for example, black women received 59.6 per cent of all bachelor's degrees awarded to blacks, 64.1 per cent of master's degrees, and 45.1 per cent of all doctoral degrees awarded to blacks. However, although the pool of black women with degrees in science was larger than the pool of black men, males received more PhD degrees in all scientific and engineering fields. Likewise, Hispanic, native American, and, to a lesser extent, Asian, men earned more degrees in science and engineering at every level (Malcom, 1983). Malcom explains that double barriers, those

related to race or ethnicity, which hold down the participation rate of minorities, and those related to gender, which limit the participation rate of women, both affect minority women.

Extensive data have been gathered on the entrance and retention of women to medical and engineering schools in the US. A close examination of the data reveals the actual gains made by minority women.

Medical Schools

Table 1 indicates the number of majority and minority men and women admitted to the first year of medical school in 1983. Overall, in 1984 minority women made up 20 per cent of first year entrants; while women, both minority and majority, composed 48 per cent of all new entrants.[4] Two decades before, when medical schools had quotas on the number of 'female beds' or admission slots for women, Cornell University Medical School in New York accepted two women. In 1984, women composed 60 per cent of its entering class. Men still have a slight edge over women in acceptance rate to medical schools. In 1983, the acceptance rate for men was 49.3 per cent; for women, 47.1 per cent.

Table 1: First year new entrants to US medical schools

Racial/Ethnic Group	*Men*	*Women*	*Percentage of total*
US CITIZENS			
White	9,299	4,266	82.3
Black	527	445	5.9
American Indian or Alaskan Native	33	33	0.4
Mexican American (Chicano)	174	91	0.6
Puerto Rican (Mainland)	58	38	0.6
OTHER US STUDENTS			
Asian or Pacific Islander	627	322	5.8
Puerto Rican (Commonwealth)	153	69	1.3
Other Hispanic	165	72	1.4
Unclassified	4		
FOREIGN	70	23	0.6
TOTAL	11,110	5,370	

Note: US citizens redefined in 1981–82 and thereafter to include permanent residents.
Sex-ethnicity figures include only students entering medical school for the first time.

Source: 1980–81: Association of American Medical Colleges Student Record System.
1981–82 and thereafter: fall enrollment surveys in (1984) *Project on the Status and Education of Women*, 13.4, Spring, p.7.

Women, including minority women, have moved rapidly into other medical professions. For example, in 1970, women were 1 per cent of dental school students, while they were 17 per cent in 1980. In 1983, women made up 24 per cent of all first year dental students. In the traditionally male dominated fields of veterinary medicine, women are now about half of first year classes. Table 2 provides more complete data on a variety of medical careers and indicates graduation as well as entrance rates.

Table 2 Proportion of women enrolled and graduating in the professions, 1982 (percentage)

	Enrollments		
	1st Year	*Total*	*Graduates*
Medicine	30.8	27.9	25.0
Osteopathic medicine	23.9	20.9	18.3
Dentistry	21.7	18.7	14.9
Veterinary medicine	50.0	46.4	35.4
Optometry	26.7	23.7	20.1
Pharmacy	53.2	50.6	47.0
Podiatry	20.7	16.4	10.5

Source: Scientific Manpower Commission (1984) in *Project on the Status and Education of Women*, 13, 3, Winter, p. 3

Taking a closer look, data show that minority females made impressive gains in entrance to dental schools. For example, in 1976 minority women composed 2.7 per cent of all students preparing to be dentists, but by 1983, they held 6.1 per cent of all dental school slots.[5] However, for other fields the data show poor entrance rates. For example, blacks, both male and female, were only 1.7 per cent of all optometry students in 1983. This represented an increase of 0.7 per cent in a decade. Overall minority enrollments in first year medically related schools increased from 12.4 per cent in 1977 to 16.8 per cent in 1984.

Engineering Schools

Since the early 1970s, there have been special programs in the US to recruit women into engineering schools and programs. Indeed, one of our success stories has been the rise in number of women engineers from 0.4 per cent to 13.0 per cent in a decade. Recent data provide information concerning the entrance and graduation rates of minorities in engineering curricula. Unfortunately, data are scarce concerning minority women. It is predicted that minorities (male and female) will

continue to increase their share of engineering degrees through 1987. Asians will receive a disproportionate number of bachelor degrees in engineering.

While black, American Indian, Asian and Hispanic women make up 8.3 per cent of the total labor force, they comprise less than 1 per cent of all PhD scientists and engineers. Minority women accounted for 9.7 per cent of all full-time undergraduate enrollment in the fall of 1980, but they comprised only 5.2 per cent of graduate enrollment. They were 0.9 per cent of graduate enrollees in engineering, 1.3 per cent in the physical sciences and 3.5 per cent in the biological sciences.

Employment Mobility

Generally, employment opportunities, like educational ones, vary greatly among women from different minority groups. For example, Asian women, Filipinos, Chinese and Japanese have the highest labor force participation rates, while minority women with the lowest average years of schooling; that is, native Americans, Puerto Ricans, and Mexicans have the lowest work rates (Lewis in Stein, 1985). Type of occupation also varies among minority women. Prestige and high wages accompany professional and managerial positions. When occupation prestige ratings are calculated, one finds that Filipino women rank highest, followed closely by whites, Chinese, and Japanese women. On the other end of the scale, one finds that over one-quarter of black and Hispanic women are clerical workers.

The situation in science and engineering is different, however. Of the approximately 450,000 employed US women scientists and engineers in 1982, 85 per cent were white, 7 per cent were black, 6 per cent were Asian, and less than 1 per cent were native Americans. However, minority women are more prevalent in the sciences than minority men are.[6] Furthermore, in the past decade, employment of minority women in science and engineering has increased more rapidly than employment of white women. Both black and Asian women increased their employment rate by 400 per cent, while the rate for white women improved by 200 per cent. Furthermore, Asian women are more highly represented in the scientific and engineering work force than they are in the general one. In 1982, only 1.8 per cent of all women in the US labor force were Asian, but 6 per cent of women scientists and engineers were women (NSF, 1984).

Minority women hold prestigious positions in science and engineering fields. For example, black women are more likely to hold managerial

positions than other women are (18 per cent black, 15 per cent white, 11 per cent Asian). In universities more black, compared with white and Asian, women are found in tenure track positions. In 1981, for example, 69 per cent of black doctoral women, compared with 60 per cent of white and 45 per cent of Asian, were in tenure track positions. However, the same proportion of black and white women reported holding tenure (slightly less than two-fifths). Among doctoral women scientists and engineers, the proportion holding professional rank ranged from 93 per cent (black women) to 88 per cent (Asian women) (*ibid*).

When analyses are made concerning the labor force participation rate of minority and white women, rates vary in a narrow range over the past few years. For example, in 1982 at all degree levels, black women reported a rate of 97 per cent, compared with rates of 93 per cent for whites and 94 per cent for Asians. However, in 1981 at the doctoral level, both Asian and black women scientists and engineers had higher participation rates (95 per cent) than white women did (91 per cent). Overall, the labor force participation rates for all women scientists and engineers were high and comparable to those of men. However, their employment rates were lower than those of men in each group. In addition, under-employment and under-utilization rates were higher for women than they were for men regardless of group (*ibid*).

Although gains have been made, minority women, except for Asians, are underrepresented in the scientific and technical work force in the US. Recently, prestigious commissions have suggested that this situation has contributed to both the shortage and the limitations of our technological work force. Ways of easing the transition of minority women from one minority to another, therefore, are being sought, and they will be discussed in the next section.

Making the Transition

In 1980, a survey, sent to members of the National Network of Minority Women in Science (NMWIS), requested ways to increase the number of minority women in science. Respondents offered the following suggestions.

(i) Attitudes conducive to achievement should be encouraged. Higher self-esteem, success motivation, high academic expectations, self-discipline, willingness to assess and take risks, high regard for the value of education, and realization that educational/career objectives demand hard work and disci-

pline are all requisite for scientific studies. The respondents felt that role models, especially teachers, counsellors, parents and science speakers would be excellent sources of encouragement.

(ii) The quality of the high school curriculum and extracurricular activities should be improved. The respondents stressed the importance of piquing student interest in science at an early point in their education, of relaying the importance of science in the students' world, and of the use of stimulating teaching methods, demonstrations, field trips, and micro-computers.

(iii) Students must have access to adequate counselling and career decision information. Students need to be aware of 'the relationship between high school courses and future career options', the usefulness of science in the student's world, the education requirements for science/mathematics careers, the resulting rewards from those careers, and how to go about choosing an institution suited to the student's particular needs. (Hall, 1981)

In secondary schools, counsellors especially need to alert minority students to the pitfalls of taking 'easy' courses during high school. For example, nearly 40 per cent of minority girls interested in science reported discussing future education and training with high school counsellors three or more times a year.

Minority women must be encouraged to enter and to stay in science and engineering majors in college. For example, in the fall of 1980 minority women composed 9.8 per cent of total undergraduate enrollments in US colleges and universities. They were 5.25 per cent of graduate enrollments. Combining undergraduate and graduate students, minority women comprised 9.5 per cent. Their numbers within science and engineering departments varied both across fields and by academic level. For example, minority women were 10.27 per cent of undergraduate, 3.52 per cent of graduate and 9.5 per cent of all students in the biological sciences. In the physical sciences minority women composed 4.04 per cent of undergraduate majors and 1.5 per cent of graduate students. In engineering the figures were 2.4 per cent of undergraduate students and 0.87 per cent of graduate students. Therefore, 94 per cent of minority women undergraduate students and 93.5 per cent of graduate students were majoring in disciplines other than engineering or physical science.

Several researchers have identified barriers to potential minority women scientists in college, and they have proposed remedies. One

report suggests the colleges themselves may be at fault. Frequently, there is no 'middle of the road' path for black women; that is, they are viewed as either academic incompetents or as academic superstars (AAC, 1982). For example, black women report that they are neglected and overlooked because faculty believe them to be less committed to their studies and frequently ignore and interrupt them. Their interactions with faculty are characterized by excessive physical distance, decreased eye contact, and fewer offers of guidance or criticism. Black women undergraduates, perhaps as a result of these behaviors, frequently attribute their success to luck rather than to ability (*ibid*). Minority female undergraduate students facing such behavior, in addition to the stress of college life, are often frustrated and may wish to quit or to change majors. Several solutions for curbing attrition and field-switching among minority women are available. First, it is imperative that minority girls receive better secondary preparation. Second, minority women need access to support services in order to maintain high academic achievement and personal confidence levels during their college careers. Regular counselling, peer tutors, peer and faculty mentors, and regular monitoring of academic progress have all been suggested as methods to ease the academic and personal pathways for undergraduate minority women (Hall, 1981; NBGE, 1976). As stated by the National Board of Graduate Education (1976) '. . . [This] problem must be addressed during the high school and early undergraduate years to motivate students and ensure adequate academic preparation for advanced work in certain fields such as the natural sciences and engineering' (p. 51).

Likewise, many reasons have been suggested for the low number of minority women graduate students. Financial factors are often cited: 'Although sufficient financial aid does not insure a successful college career, it may be the major inhibiting factor for many minority students' (Kahle, 1982). Nearly 50 per cent of the respondents to the Minority Women in Science survey indicate that financial aid in the form of fellowships, grants, and loans is the most important factor in attracting minority students to graduate studies (Hall, 1981). Unfortunately, women, on the average, receive less financial aid than men do. During the 1981–82 academic year, women obtained only 72 cents for every dollar of grant money awarded to men. Since women, particularly minority women, form a larger proportion of part-time students than men do, many are ineligible to receive financial aid. Only 10 per cent of an institution's aid may be channelled to part-time students in the US. This policy effectively excludes many minority women.

The conspicuous absence of role models, especially minority

women scientists, also may be a deterrent to minority women entering graduate studies in scientific fields. In 1980, for example, black women comprised only 3.1 per cent of the faculty in higher education and only 1.5 per cent of the science faculty in higher education (SMC, 1983). The paucity of minority role models makes it more difficult for minority graduate students to develop mentor relationships with faculty. As the National Board on Graduate Education states, 'The absence of persons with advanced degrees to serve as appropriate role models for the aspiring student weakens the link between wishful thinking and the practical knowledge needed to formulate a meaningful objective and to take the necessary actions to achieve it' (NGBE, 1976, p. 101). Difficulties in establishing faculty relationships may be a formidable barrier for minority women graduate students.

In addition to the difficulties of establishing productive mentor relationships, minority students, especially minority women, have reported problems in establishing mutually supportive collegial relationships with majority graduate students (Hall, 1981). The benefits of a graduate student network include collaboration on research projects, informal teaching of methods and procedures, cooperative generation of hypotheses, and the establishment of professional contacts. They are second in importance only to the major professor/student relationship benefits and cannot be forfeited by minority graduate women aspiring to successful science careers.

Minority women graduate students, especially those from small undergraduate schools, may get caught in the 'revolving door' policy, prevalent in some doctorate-granting institutions. According to this policy, students have a specific period of time in which they must complete their qualifying examinations, preliminary examinations, and dissertation. If they delay any step in this process, they may lose financial support. This policy discriminates against any student who enters with an academic deficiency. On the average, minority students are older than majority ones when they complete a doctorate and they have longer periods between beginning and completing their degrees (NRC, 1982). Any policy, therefore, that decreases flexiblity in progress toward a degree is detrimental to minority graduate students.

Finally, minority women scientists report major difficulties during graduate studies due to sexism (NBGE, 1976). Minority women face the problems encountered by majority women in science. Not only is science viewed as 'non-black', it is also stereotyped as 'masculine'. In choosing a scientific career, therefore, minority women must overcome not one, but two, stereotypes.

Colleges and universities must improve conditions in order to ease

the access of minority women to scientific careers. For example, minority women students should be quickly integrated into the mainstream of teaching and research activities (*ibid*). Departments should promote minority access to mentor relationships as well as to the informal information networks which are of vital assistance in acquiring job placement references and contacts and in learning grant application procedures (Hall, 1981). Research universities must increase the numbers of minority faculty, both male and female, in order to provide role models for minority graduate and undergraduate students (Hall, 1981; NBGE, 1976). The 'revolving door' policy must be eliminated so that minority students with rectifiable academic deficiencies have the opportunity to complete a doctorate without unusual financial hardship (Hall, 1981).

Changes are also warranted in the work place. Recent statistics show that the mean annual income for black women working full-time is considerably less than that of white women or black men and is only 52 per cent of the mean annual income of white men (Treiman and Hartmann, 1981). Furthermore, advanced education does not necessarily remove this income disparity. The 1980 census found that the mean salary of black females with five or more years of college was less than that of black males with only one-three years of college and was less than that of white males with only one-three years of high school (*ibid*). In comparing black females with five years or more of college with white or black males of equal training, black women earned only 49.3 per cent of the white male's average salary, and less than 68 per cent of the black male's average salary (*ibid*). Even more alarming are the data analyses which produce occupational segregation indices for all occupations. These analyses show that 'occupational segregation is more pronounced by sex than by race' (*ibid*, p. 28). For example, in the period from 1940–1970, occupational segregation indices changed significantly for blacks versus whites, becoming progressively less segregated, but the indices for males versus females remained consistently high (Treiman & Hartmann, 1981). Minority women, therefore, are caught in a 'double bind', and this recent information indicates that their situation has improved little in the last decade.

Recently, reasons for inequities in the work place reported by minority women were suggested by respondents to the Minority Women in Science survey. First, they indicated that society's view of the minority woman scientist was negative, suggesting disapproval and resentment. Second, they frequently have encountered those who believe 'that minority women enjoy special privileges and advantages due to affirmative action' (Hall, 1981, p. 15). Third, minority women scientists face all of the obstacles that women scientists face. In addition,

minority women may be inaccurately prejudged as 'non-performers' (Hall, 1981).

For example, black women scientists have been viewed as non-performers by employers, whose attitudes are critical to the woman scientist's career. MWIS survey respondents stated that there is a significant failure to recognize the potential and accomplishments of minority women scientists (*ibid*). They have endured lower pay, slower advancement, less utilization of their talents, fewer rewards, less recognition, and less job security (*ibid*). In addition, they are frequently overloaded with committee work during which they are called upon to offer 'the black woman's point of view' but seldom their own personal opinions (*ibid*).

Perhaps the most frustrating situation black women face is the negative attitudes of co-workers and colleagues. Science is a social discipline and profits from collaboration and cooperation among scientists. Minority women scientists, viewed as a threat to co-workers, encounter resentment and prejudice, and they may be ignored when colleagues choose collaborators, when training or job opportunities open, or when social functions are planned (*ibid*). These inequities result in a professionally crippling isolation in which minority women suffer a general lack of 'recognition as a legitimate and valuable part of the peer group' (*ibid*, p. 17), and the benefits which accompany that membership.

Changes in both the classrooms of schools and colleges and the laboratories and offices of industries and universities are needed to help minority women move into science. Minority women who face discrimination as both women and as members of a minority group are underrepresented in the scientific labor pools of all nations. The changes suggested will enable more women to move from a minority position in society to a minority one in science. As they do so, it is anticipated they will bring to science a new perspective. In the words of a 15-year-old girl in Indiana,

> There are some women scientists, but men have been in it longer. Women can do the same job as men. They may have a different way of thinking and may improve science. (Kahle, 1985, p. 234)

Notes

1 In the United States in 1977, approximately 96 per cent of all elementary teachers were women, whereas women made up only 24 per cent of all

secondary science teachers.

2 The retention rate for Asian students is high; for specific subgroups (Korean, Japanese, Chinese) it exceeds the rate for white students.

3 The lack of consistency in reporting data by group reflects lack of information on specific groups.

4 Although the overall data are fine, blacks are underrepresented in proportion to their population (11.6 per cent). Asians, on the other hand, are overrepresented for their proportion of the population.

5 This gain is impressive when compared with minority males as dental students. In 1973, minority males were 8.2 per cent of the dental student population and 10.6 per cent of it in 1983.

6 In 1982, 92 per cent of male scientists and engineers were white, 2 per cent were black, 4 per cent were Asian, and less than 1 per cent were native Americans.

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5 *Women in Radio Astronomy — Shooting Stars?*

John Irvine and Ben R. Martin[1]

Abstract

This article describes the results of a study examining the long-term employment profiles of British doctoral students of radio astronomy. In particular, attention is focussed on explaining the divergence in the subsequent career paths of men and women. Data on the 'quality' of students' doctoral work and their immediate post-doctoral employment suggest that the relative lack of career success shown by women astronomers is more likely to be the result of social factors relating to their role within the family rather than any inherent lack of ability as scientists or direct discrimination in employment.

Introduction

With the growth of the women's movement over the last fifteen years, the continued underrepresentation of women in higher status and better paid occupations has become a central feature of both popular and academic discussions. This underrepresentation is particularly pronounced in science as can be seen from table 1, which draws together the most recent official statistics on the relative numbers of females in school and university science in Britain.

There are several possible reasons for women's underrepresentation in science. It might, as some have suggested, be a product of genetically-based differences in ability between the sexes which favour male achievement in science. However, as we have argued elsewhere (Martin and Irvine, 1982), the evidence to support such a view is unconvincing.

Alternatively, the underrepresentation could be the product of

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Table 1 A cross-sectional view of the position of women in British academic science (1984)

	*'A' level students**		*Undergraduate students*		*Post graduate students*		*Lecturers*		*Senior lecturers and readers*		*Professors*	
	M	F	M	F	M	F	M	F	M	F	M	F
Relative percentage of males (M) and females (F)	61.5	38.5	66.7	33.3	77.0	23.0	89.2	10.8	97.2	2.8	99.1	0.9
Ratio of males to females	1.6		2.0		3.3		8.2		35.4		112.2	

* The definition of 'A level science student used here is that of pupils taking two or more 'A' level courses, at least one of which is a 'mathematics/science' subject. For university students and staff the UGC classification for 'science' is used; this excludes medicine, dentistry, health, engineering, technology, forestry, and veterinary science.

Sources DES (1985)
UGC (1984)

various social factors: the masculine image of science may deter girls from choosing to specialize in it at school; those who actually succeed in entering science may, because they are in a minority, be subject to implicit or even overt discrimination; the role of women in the family (and the general subordination of their careers to those of their husbands) may mean that women scientists are working under very different conditions than men. Unless one accepts that genetically-based differences in cognitive skills between the sexes completely account for the position of women in science, then the situation portrayed in table 1 is not just another example of the unequal opportunities afforded to women in our society: it also represents a vast drain of intellectual resources. If the ratio of women to men scientists at senior career levels were raised even to that in schools (where females are still underrepresented), this would yield a significant increase in the pool of highly skilled scientific personnel. Such a loss of potential human resources is especially pertinent at present since the shortage of trained scientists and engineers in Britain has often been pinpointed by policy-makers as one of the causes of the country's woeful industrial performance.

Given that many women fail to reach the higher levels of academic science, it is worth examining the careers of those who have proved they have the drive and ability to gain doctorates. Is Graham (1970) correct in suggesting that there is little to choose between the academic ability of those women and men who obtain PhDs in science? And, if so, what factors other than scientific competence might explain their subsequent highly divergent career profiles?

It is far from easy to evaluate scientific competence or performance — that is, to measure the extent to which contributions are made to the advance of scientific knowledge. However, while there are no simple measures to draw upon, a number of indicators do exist which at least partly reflect the degree of success in contributing to scientific knowledge (cf. Martin and Irvine, 1983). In particular, one can consider the output of scientific papers published by researchers. Using this measure, there is some evidence that women scientists are on average less productive[2]. While the productivity of men and women is similar at the start of their scientific careers (that is, among recent doctoral graduates — see, for example Simon *et al.*, 1967; Cole and Cole, 1973), differences emerge soon after this (Zuckerman and Cole, 1975; Cole and Cole, 1973). Since the productivity of unmarried as well as married women scientists declines, this cannot apparently be attributed solely to women becoming more involved in the demands of their families. Zuckerman and Cole (1975) suggest that women scientists

> spend less time on research, have more limited access to resources for it, and are less fully integrated into the scientific community within their fields of specialization, thus reducing the probability of carrying out useful scientific enquiry. (p. 93)

Women may publish less, but do their papers on average make a smaller impact on the advance of scientific knowledge than those of their male counterparts? To explore this question, one can examine the number of times other researchers refer to or cite each scientific publication (using the *Science Citation Index*), this being an indicator which partly reflects that publication's impact on the advance of knowledge (cf. Garfield, 1979). Unfortunately, the evidence is ambiguous: Cole and Cole (1973, pp. 138–9) find that women's papers are cited less than men's, while Teghtsoonian (1974) claims in contrast that 'there is no support . . . for the contention that women publish inferior, ie. less highly cited, work' (p. 266).

On the related question of the recognition women receive for their work, there is similarly conflicting evidence; Cole and Cole (1973) claim 'there is virtually no difference in the recognition of men and women scientists in terms of the awards they are likely to receive' (p. 144), while Astin (1972) finds that 'even when women publish as much as men, they receive less recognition in the form of high rank and tenure' (p. 380). This apparent discrepancy in the evidence is partly the result of using different indicators of 'recognition', with the Coles employing honorific awards[3] and other authors preferring measures based on job-status. In terms of the latter, there can be little doubt that women do end up in lower positions than their male colleagues (see, for example, Vetter, 1975).

This raises the question of the extent to which women suffer discrimination in the allocation of opportunities and awards by a predominantly male scientific community. As regards employment and promotion, are women generally felt to be less capable than similarly qualified male competitors for positions? Or are they judged to be a less reliable long-term investment in that there is some likelihood they will leave to have children (cf. Zuckerman and Cole, 1975, p. 88)? The evidence for the existence of such sexual discrimination in science is equivocal.[4] Whatever the case, it may not be 'active' discrimination which is most responsible for filtering out women scientists. Discrimination can take less open forms. In an article in *Science*, White (1970) discusses some of the features of a research environment conducive to productive scientific work — for example, challenging interaction with other professionals is generally needed for creative research, while

promotion of one's ideas by more eminent scientists may be required before they are recognized by the wider scientific community. In both cases, women often encounter greater difficulties than men. As Simon *et al.* (1967) observe,

> the 'problem' which bothers the woman PhD who is a full time contributor to her profession is that she is denied many of the informal signs of belonging and recognition. (p. 236)

The situation takes on the nature of a vicious circle. The comparative rarity of women scientists may result in many of their male colleagues regarding them first and foremost as women rather than scientific peers. Consequently, they are less well integrated into the scientific community and may be denied access to the informal or tacit knowledge that cannot be found in the literature (cf. White, 1970, p. 414). This partial exclusion from the informal knowledge-transfer mechanisms, which can be crucial in a fast-moving science, restricts their ability to excel as researchers and in turn ensures that the number of eminent women scientists remains small.

In what follows, we present a case-study in which cohorts of men and women radio astronomers were followed through successive stages of their subsequent careers. The dynamic nature of the study provides information of a different type to that from the usual static evaluations of women in science, which tend to focus on a cross-section of the scientific community at a particular time, or, at best, on a series of such cross-sections.

Women in Radio Astronomy

The data presented below on gender-related differences between doctoral performance and subsequent career patterns were not the result of a deliberately planned investigation into the position of women in science, but the by-product of a broader assessment of basic-science policy in Britain. As part of the study, a postal survey of all former radio astronomy students[5] was carried out in 1979 in order to establish the educational value of the training they received. The differences between the experiences of male and female respondents were so striking that we were encouraged by colleagues interested in the question of women in science to publish the results. And although the number of women in the sample is small, the results do seem significant, even if they are not conclusive.

In common with other branches of physics, radio astronomy is characterized by extremely small numbers of women researchers. Since

the emergence of the specialty in the late 1940s, only fourteen women had by 1979 registered for the PhD degree at Cambridge or Jodrell Bank compared with 301 men, the proportion of 4.7 per cent being slightly less than that for physics as a whole.[6] Women are even less well represented in the ranks of the academic staff, as table 2 demonstrates.

Table 2 British university radio astronomers by status and sex, 1979

Professors		*Readers and senior lecturers*		*Lecturers*		*Senior research fellows (or equivalent)*		*Fellows*	
M	F	M	F	M	F	M	F	M	F
5	0	5	0	18	0	3	0	9	1

In order to identify the factors explaining the position of women in radio astronomy, we shall concentrate on the following questions: how well do women perform in the research they carry out for their PhD? What are their subsequent career patterns, and how do they relate to scientific competence as indicated by doctoral performance? In particular, what are the principal reasons why women have changed jobs, and how do these compare with those given by men?

The Doctoral Performance of Women Radio Astronomers

As noted earlier, a number of indicators can be used to explore whether male and female post-graduate students differ in their levels of research performance. Judging from the figures in table 3 on success and failure rates for the PhD, one can see that women radio astronomers have performed, if anything, rather better than their male counterparts, with a pass rate of 100 per cent for those in our sample compared with 80 per cent for men.[7] Another indicator is the number of years taken to complete the degree, and in this respect the men did slightly better than the women, although the difference (4.3 years compared with 4.8) may not be very significant because of the small number of women involved.[8]

Table 3 Success rates for radio astronomy PhD students (1947–77)

	Number registered for PhD	*Number not yet submitted*	*Number obtaining PhD*	*Number failing PhD*	*Average time to obtain PhD (years)*
Male	305	45	204(80%)	52(20%)	4.3
Female	14	1	13(100%)	0(0%)	4.8

A third indicator is the number of scientific publications produced by women students[9] and by their male peers (that is, those men beginning their PhD research at the same time and at the same observatory) on the basis of their thesis research (defined as work published in the four-year period after registration for the degree), while a fourth is the number of citations gained by each of those publications (which gives some indication of the impact of their papers on the scientific community). Data on the numbers of publications and citations[10] for each woman student and her cohort of peers are shown in tables 4(a)–(h).[11] When the figures for publications and citations are aggregated for all the women and their male counterparts in our study, certain patterns become clear. As can be seen from table 5, while constituting 17.3 per cent of the population of eighty-one astronomers, the women produced 20.9 per cent of publications. In turn, these publications earned 18.8 per cent of all citations. Thus, the women performed as well as, if not marginally better than, their male peers in terms of these two bibliometric indicators.

Table 5: Numbers of publications and citations

	Women	*Male peers*	*Total*
No. of scientists	14(17.3%)	67(82.7%)	81
No. of publications	51(20.9%)	193(79.1%)	244
No. of citations	370(18.8%)	1594(81.2%)	1964

To summarize, three of the four indicators of scientific performance employed here suggest that the women PhD radio astronomers performed at least as well as their male peers in their early scientific work. Indeed, these three indicators suggest a slightly better performance on average by the women, but the small differences between the sexes may not be statistically significant, just as the slightly better performance of the men in completing their PhD promptly may be an artefact of the relatively small samples. What is clear, however, is that any subsequent lack of success in the scientific careers of the women cannot be attributed to inferior performance during their PhD research.

Subsequent Career Paths

Data on the career paths of the nine oldest women astronomers and their male peers are shown in tables 4(a)–(h). Given their competence at doctoral research, these women appear to have gained scant reward

Table 4(a) – Cohort analysis for female/male radio astronomy students 1949. NK = not known; NS = not stated.

Name of Student	Date of Birth (Degree)	Date Awarded	Years to Degree	Subject of First Degree	Number of Subsequent Academic Publications in Each Time Period				Post 1st	Present Post	Second Post	Present Post	Third Post	Present Post	Present Post	Present Post	Post	Present Post	Post	Present Post	Present Post	Present Post	Present Post	Present Post	Present Post
					1960	1965																			
W1		1960s	3																						
W1	1940 MARY [NAME]	1961 [YEAR]			3	1																			
W2	NK	1961		1					2																NK
W3																									
M1																									
M2	NK	1961		1					1																NK
M3		1962	3	1	3	10																			
M4		1962	3	10	3	3																			
M5	NK	1962	3	1	3	1																			

Table 4(b) 1955–1957

					1966	1968	1970	
W/	I	PASS	3	3	3	2	1	
MI	SA	PASS	5	1	4	0	0	
MT	BI	PASS	4	2	14	12	1	
MB	FOR EIGN PEOPLE	PASS	5	1	0	0	0	
M9	0 2	FAIL (MSc)		0				
M10	I	PASS	4	1	11	8	0	

Table 4(c) 1957–1958

W1	1	PASS	4	3	11	11	11																	
M9	0.2			0																				
M10	1		4	1	11	11	11																	
M11	0.1	PASS	4	1	11	11	11																	
M12	0.2	PASS	3	0	10	10	10																	
M13	0.1	PASS	4	2	11	11	11			2														

Table 4(d) 1960

					1960	1968	1970																	
W4	5K	PASS	11	1	2	0	0																	
W5	5K	PASS	5	1	4	4	1																	
M14	1	PASS	15	1	4	2	0																	
M15	1	1st		2																				
M16	1	PASS	1	4	4	4	0																	
M17	1	PASS	3	1	3	3	1																	

Table 4(e) 1963

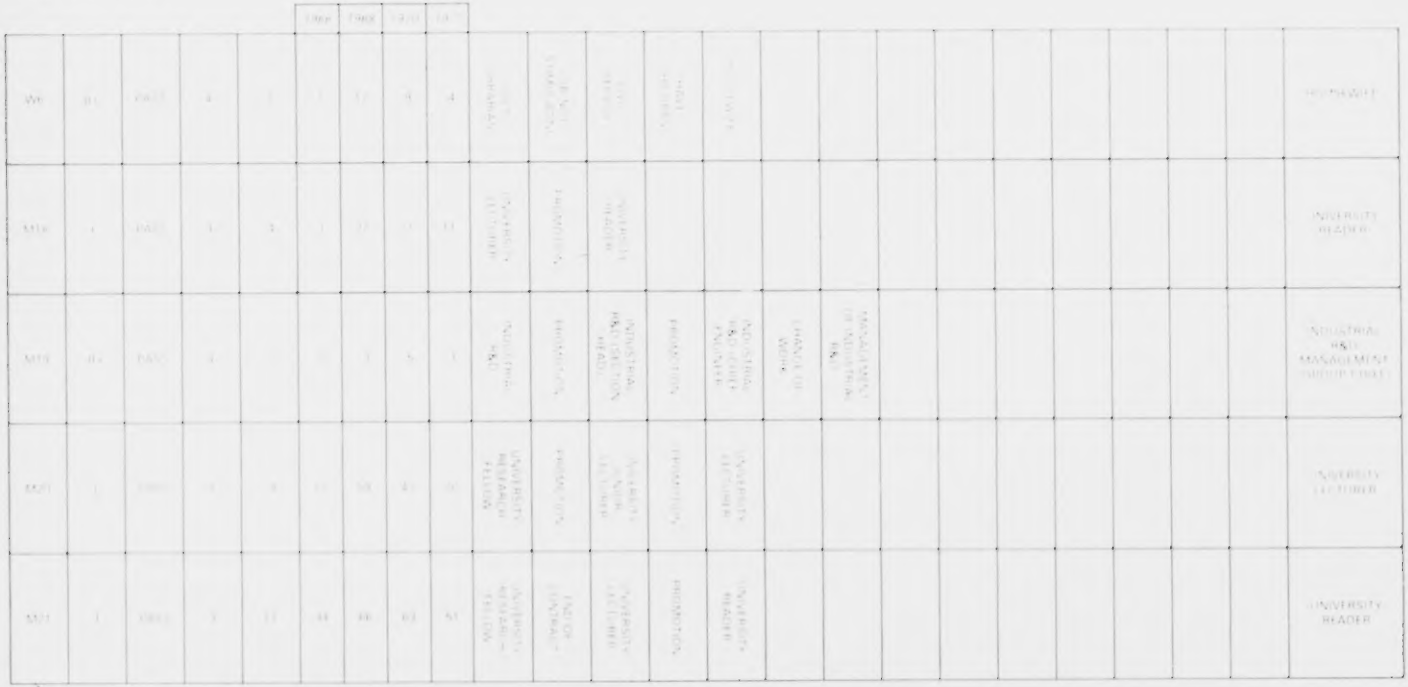

Table 4(f) 1965

					1968	1970	1972	1974															
W7	B1	PASS	3	3	108	29	15	11	UNIVERSITY RESEARCH FELLOW	HUSBAND MOVED	JAMAICA	FOUND JOB	PART TIME UNIVERSITY COMPUTER PROGRAMMER	PROMOTION	PART TIME UNIVERSITY RESEARCH								PART TIME UNIVERSITY RESEARCH FELLOW
M1	1	PASS	1	3	14	28	41	25	UNIVERSITY RESEARCH FELLOW	RETURN TO UK	INDUSTRIAL R&D	DESIRE TO RETURN TO ASTRONOMY	UNIVERSITY LECTURER										UNIVERSITY LECTURER
M23	1	PASS	1	11	35	60	46	30	UNIVERSITY RESEARCH FELLOW	PROMOTION	UNIVERSITY JUNIOR LECTURER	END OF CONTRACT	UNIVERSITY SENIOR RESEARCH FELLOW										UNIVERSITY SENIOR RESEARCH FELLOW
M24	B1	PASS	1	1	13	8	9	4	GOVT R&D	PROMOTION	MANAGEMENT OF GOVT R&D												MANAGEMENT OF R&D (GOVT)

Table 4(g) 1968

W8	5X	2000	0	1	4	0	1		COMPUTER PROGRAMMER (GOVT)	TEACHER	PUBLISHING																	GOVT SCIENTIST
M25	1 III	PASS	0	0					COMPUTER PROGRAMMER	ENTOMOLOGIST	TECHNICAL WRITER (GOVT)	PUBLICATIONS	CONSULTANT															GOVT SCIENTIST
M26	II 2	PASS	0	0					COMPUTER PROGRAMMER	ENTOMOLOGIST	GOVT LAB																	GOVT SCIENTIST
M27	II 2	PASS	0	1	1	0	0		UNIVERSITY RESEARCH FELLOW (GOVT)																			UNIVERSITY RESEARCH FELLOW (GOVT)
M28	II 2	PASS	0	0					SCHOOL TEACHER	ENTOMOLOGIST	INDUSTRIAL R&D	ENTOMOLOGIST	PUBLISHING (TRANSLATION)	PERSONAL	GOVT COMPUTING												GOVT COMPUTER PROGRAMMER
M29	II 2	PASS	0	0					COLLEGE LECTURER	ENTOMOLOGIST	MILITARY R&D (GOVT)																	GOVT SCIENTIST

Table 4(g) continued

					1970	1972	1974																	
M30	N4	CAS5	4	7	6	1	11		UNIVERSITY RESEARCH ASSISTANT	PROMOTION	ACADEMIC RESEARCH FELLOW	PROMOTION	ACADEMIC LECTURER											UNIVERSITY LECTURER
M31	N3	CAS5	3	11					UNIVERSITY RESEARCH FELLOW	END OF CONTRACT	UNIVERSITY LECTURER													UNIVERSITY LECTURER
M32	N5	CAS		11					COMPUTER PROGRAMMER															UNIVERSITY COMPUTER PROGRAMMER

Table 4(b) 1969

M.Sc.	II	PASS	4	1	0	1	0	1																UNIVERSITY RESEARCH ASSISTANT
M.Sc.	II	PASS	4	0	—	—	—	—														—		UNIVERSITY RESEARCH FELLOW
Ph.d.	III	PASS	6	1	1	5	5	4														—	—	UNIVERSITY LECTURER
M.Sc.	III	PASS	4	0	3	23	24	4														—	—	UNIVERSITY RESEARCH FELLOW
M.Sc.	I	PASS	3	0	2	8	8	1														—	—	UNIVERSITY LECTURER

for their efforts, at least in comparison with their male peers. For example, W1 was at the time of our survey still only a senior lecturer over twenty-five years after obtaining her PhD, while two of her three male colleagues with academic careers (only one of whom had published more as a student or had earned more citations) had gained chairs and the other the equivalent of a readership within fifteen years of completing their PhDs. Similarly, W2 was only a temporary university lecturer while her peers included a reader, a senior lecturer and an Oxbridge lecturer.

W3 and W7 were two of the most successful PhD students, the former publishing more scientific papers than any of her peers and the latter earning more citations. On completing her PhD, W3 was rewarded with a university lectureship (which none of her male peers earned until a number of years later), but had to sacrifice this and several subsequent jobs because her husband moved. Although she attained a fairly senior position in industry, her scientific career would surely have been more successful had it not been so disrupted by family commitments. W7 has, if anything, been less fortunate. After being directly responsible for a major astronomical discovery as a PhD student, she encountered great difficulty in finding suitable employment after her husband moved, and ten years later was still only a part-time research fellow, while her two male peers who remained in academic research had reached the positions of university lecturer and senior research fellow respectively.

What are the reasons for the lack of success of the women scientists relative to their male peers? First, one should note that, in terms of their first jobs, most of the women did as well as the men. Twelve out of fourteen were able to gain academic employment (and one of the remaining two became a part-time lecturer on resuming scientific work after having children). At this stage, there were no significant differences between them and their male colleagues, and were they men they would generally have been set for successful careers. The divergence in career paths occurred fairly rapidly after the first job, as the demands of their husband's career (all but one of the women in our survey were married by this stage) severely restricted the employment choices available to the women. This can be seen in the reasons given by the survey respondents for moving from their first and subsequent jobs. The various categories of reasons reported are summarized in table 6.

Although the number of scientists in our sample is small, the results are striking. Men normally change their job because they are promoted (given as the main reason in 45 per cent of cases), because their interests change (21 per cent) or because a temporary contract expires (24 per

Table 6 Reasons for changing employment

Main reason for changing employment	*Number of times mentioned as the main reason for change*		*Percentage of times mentioned as the main main reason for change*	
	M	F	M	F
Promotion	43	5	45	17
New/changing interest	20	2	21	7
End of temporary post	23	3	24	10
Spouse moved	0	8	0	27
Family commitments (e.g. babies)	1	5	1	17
Dissatisfaction/problems with job	3	3	3	10
Other reasons (e.g. personal, geographical, etc.)	6	4	6	13
Total	96	30		

cent). By contrast, these three reasons are cited as major in only 34 per cent of the job changes by women. Their choices of new employment are determined principally by family-related pressures[12], with 'husband moved' (27 per cent) and family commitments such as babies (17 per cent) together accounting for 44 per cent of job changes (compared with a figure of just 1 per cent for men). In short, when changing jobs, men are normally able to give absolute priority to choosing a post that will further their career or one that is seen to be interesting, and their place of residence and family commitments are made to fit in with these overriding concerns.

For women, the position is far more circumscribed: the most common reason for changing job is that her husband has moved. These findings lend support to the claim by Graham (1970) that

> The chances are that, if she [the woman scientist] is married, her place of residence has been selected because it offers the best position for her husband, not for her. (p. 1287)

As one of our respondents resignedly remarked in giving the reason for one particular job change: 'Husband changing to job in another part of the country — all change!' Thus, to explain the relatively unfulfilled career potential of this sample of women scientists, there is no need to posit the existence of innate differences in ability between the sexes nor any need to invoke open discrimination[13] against women as an explanation (although, as noted above, informal discrimination may be a factor). Instead, their failure to reach senior positions can be linked to the lower level of priority given to considerations about their own careers each time they change jobs. For each move, married women scientists

normally have a far more restricted choice. They are therefore more likely to accept a less satisfactory post offering fewer chances for improving their career prospects. It is perhaps not insignificant that a higher percentage of women than men (10 per cent compared with 3 per cent) cited dissatisfaction with their existing position as the main reason for changing employment, as Kashket *et al.* (1974) arrived at a similar conclusion:

> women, especially married women at the doctoral level, feel dissatisfied with the positions in which they find themselves. Their jobs are less likely than men to fulfil their expectations or to be in accord with their view of their abilities. (pp. 492–3)

In an unsatisfactory job, the woman scientist is less likely to achieve the research performance needed to ensure that her subsequent position is a high-status one. Consequently, her next employment choice will probably be restricted not only by family commitments but also by an inferior scientific performance in her previous post. As each scientist may change employment half a dozen times in a working lifetime, one can see that after just two or three job changes[14], each made successively more difficult by the limited potential of previous ones (limited, that is, in relation to those taken by male peers), the result is a rapid filtering out in the number of women reaching senior positions in science.

Conclusions

In this study, we found no evidence that the divergent career paths of women and men radio astronomers are the result of differences in scientific ability between the sexes. The early research performance of radio astronomy doctoral students, female and male, is very similar, indicating a broadly equivalent level of ability. As a result, differing social pressures on men and women scientists must be considered responsible for preventing women from achieving their full career potential. Early promise gives way to the frustration of unfulfilling jobs and any initial brilliance fades quickly into obscurity much in the manner of a shooting star.

The inequalities of opportunity for women demonstrated here stem not so much from within science as from the wider society. To a great extent, inequality can be said to begin at home. The results described here on the main reasons scientists change jobs complement the findings of Kashket *et al.* (*ibid.*) on the circumstances under which men and

women microbiologists would consider changing geographic location when presented with the opportunity for professional advancement:

> The response for women and for men was dramatically different. Excluding those persons unwilling to move at all, 93 per cent of the women doctorates answered that they would move only if their husbands obtained a satisfactory position first. In contrast, 83 per cent of men doctorates indicated that they would move whether or not their professional wives had satisfactory prospects for employment. (p. 493)

If the problem of the underrepresentation of women in science is to be obviated, a better balance between the work and family commitments of women and men must be struck.

Nonetheless, it would be misleading to blame the filtering out of women from science, and probably from other demanding and high-status professions, entirely on inequality in the home — family attitudes and pressures reflect, and are reinforced by, societal attitudes and pressures. Not only is a better balance of priorities between the sexes needed within the home, but there must also be a substantial revision in the norms and institutions of society at large, particularly concerning the roles of men and women that society encourages and reproduces. As long as women are socialized into defining their status principally in terms of their families, while men continue to define theirs in relation to their employment, there seems little doubt that the gross underrepresentation of women at the senior levels in science and perhaps most professional careers will remain. Only when work becomes less dominant in the lives of men can it become more dominant in the lives of women (cf. Rossi, 1965, p. 1199). Then we might see an end to the vast wastage of human resources implied by the extensive filtering out of women from science.

Notes

1 No order of seniority implied (rotating first authorship). The results reported here stem from a research programme funded by the Economic and Social Research Council on the assessment of British 'big science'. The authors are also grateful to the Leverhulme Trust for financial support during the preparation of this paper. A more detailed version of the paper was originally published in *Women's Studies International Forum* (Martin and Irvine, 1982).

2 This, however, is by no means universally accepted. Guyer and Fidell

(1973 p. 160) in their study of psychologists 'find little support in their data for the contention that there is a true difference in productivity of men and women psychologists'.

3 Reskin (1976, p. 610) produces results which suggest that post-doctoral awards cannot be used as honorific measures as they are by the Coles.

4 See, for example, Fidell (1970), Lewin and Duchan (1971), and Cole and Cole (1973).

5 That is, all former postgraduates from the two British radio astronomy centres: the Nuffield Radio Astronomy Laboratories (Jodrell Bank) at Manchester University and the Mullard Radio Astronomy Observatory at the University of Cambridge.

6 The proportion of PhD degrees in physics awarded to women was 5.8 per cent in 1975 (see UGC (1977) *Statistics of Education, 1975*, 6). This figure has been rising slowly over time. The most recent data show that in 1984 11.9 per cent of all physics postgraduates were women (UGC (1984)).

7 This excludes students who began their PhD less than five years before our study and who had not yet submitted a thesis.

8 If the woman who took eleven years is excluded, the remaining twelve took an average of 4.3 years, that is, the same time as men.

9 This includes all publications and not just those on which the student was the first-named or sole author.

10 These figures have been obtained by manually scanning the *Science Citation Index*, and include citations to all work for which the student was one of the authors. The number of citations has generally been taken every two years over a six-year period except where this was impossible, in particular for the very earliest students (the *Science Citation Index* only began in 1961).

11 In the case of table 4(b), there were no male peers for W2, so the cohort has been extended to include those beginning their PhD the year before and the year after. This has also been done in table 4(c) to ensure a reasonable cohort size. The result is that M9 and M10 are included in both tables.

12 Cf. Kashket *et al.* (1974, p. 492), who found that women mentioned limited mobility five times more frequently than men as the reason they were in their present positions.

13 Only one of our respondents mentioned the problem of discrimination, observing that she felt it was more difficult for a woman to get a job than a man.

14 The first two or three posts may well be the most crucial in determining the degree of success in a scientist's career, since the peak of creativity is often claimed to be reached in the late twenties and early thirties (cf. Lehman, 1953). If a woman scientist has to make sacrifices at this stage by fitting her career around her husband's, she may not be able to make good these losses to her employment prospects later on (cf. Rossi, 1965, p. 1199).

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6 *On Being a Scientist*

E.A. Johnson

Why Do Science?

One of my first boyfriends was a Methodist minister. He also happened to be a physicist. He invented sound systems in his spare time, in the days just before hi fi, and managed to transform my family's record player into a thing of magic. Suddenly, there was real Chopin, played by a professional, in our own living room. What a pity that I found the physics behind this as boring as my boyfriend found it fascinating. —

The minister was a physicist I knew; Einstein was one I didn't know — personally, that is. But who could have helped hearing what Einstein had found out about the nature of time and space. It was mind-boggling, but intensely interesting. When the time came to choose between boyfriend and university, it was the latter — and Einstein — who won.

Why should young people go into science? It is often said that they should do so because it is good for the national economy, or that girls in particular should, so that there will be as many women as men in science. These reasons are boring and rather trivial, and it is hard to imagine that such considerations stir the spirits of the young.

People become scientists for all sorts of reasons. But my own, I think, are very common. The things we learn about the world, through science, are simply very exciting. There is an order and a beauty in the world that lies hidden. Science is the formation of a partnership between human understanding and the rest of creation, to bring out that hidden beauty and make it explicit. When you become a scientist, you form this partnership too. What you discover will often be new only to yourself; sometimes it may be new to everybody.

The next thing to be said is that it is *fun* to do science. This very important fact was pointed out long ago by King Solomon[1]. Wisdom, he

said, is a master craftsman, ever *at play* in the world. Science is a kind of play. To be a scientist is to couple the wonder and imagination of a child with the creative understanding of the adult. Doing science is fun.

Moreover, doing science is an adventure. When you set out on a voyage of scientific discovery — maybe struggling over an example from an old 'A' level exam, or perhaps starting on your PhD research project — you don't really know what is going to happen next, or how. The sensation can be exhilarating. It is often terrifying. What's needed at times is the courage to sail over the rim of the world, and find out what's on the other side. Earlier travellers have found wonders. But what will happen to you?

People sometimes say that science is 'about things' and not 'about people'. Be that as it may, science is very much *for* people. There is the obvious way in which today's basic discoveries in science become the practical benefits of the next decades; but that argument is a two-edged sword to be used with care. No, Einstein's science is *for* people in the far more basic way that Shakespeare's plays and Beethoven's symphonies are *for* people.

Why do science, then? Because it is *worth* doing. The science created in the past few generations is one of the glories of the present age. What a privilege to take part. And what enormous fun.

What About Women?

Somehow, lots of women in Britain have lost out on the enjoyment of science. Take my own subject, physics, which is a kind of keystone to the other sciences. Even at 'O' level, girls have already dropped out to such a degree that there are three boys to every girl[2]. Why don't more girls choose to do physics?

Some answers are easy. Personal preferences can run in other directions. There are lots of other good things to be done. What is harder is to find the reasons behind these preferences.

Some answers point up things that can be changed. Many girls get very poor science teaching, and some don't get much encouragement either. This is a bad thing, but it is not always fatal, thanks to the general contrariness of human nature. Janet[3], who does biomedical research, recalls 'In my school, hardly any girls did physics. It wasn't something you were supposed to do. I thought, *I'd* show *them!*'.

Some answers are quite uncomplimentary about our present society. I've been asked at various times why ever did I choose to do something as demanding as physics. Such questions imply that it is

somehow unfeminine to do things that are hard, or that take a lot of thinking. Perhaps people who ask this don't quite see the other side of this thought — namely the prejudice that it *is* feminine to be slack and lazy, and feminine to turn off one's mind.

Then there is the military connection. The military connection is a two-step affair. The first step relates scientific to military, the second step relates military to masculine. Girls in Britain tend to think science is masculine[4], not least because of the military connection. Other reasons include the preponderance of men in science and engineering, and the presentation of science at school and in the media as a masculine activity. These images tend to put girls off science, and can colour their attitude to such an extent that, even when they do science at school, they don't do it as well as they could[4].

Science, Masculine and Feminine

Science has all sorts of uses. Some of these kill people. Some of these cure them, clothe them, and feed them. The military connection does not make science masculine.

Lack of women who do science does not make it masculine either; in fact, the sex ratios for science in Britain can seem quite unusual to visiting foreigners. In many other parts of the world, women and men come into physics in equal numbers[5]. And in Portugal, according to Anna, a nuclear physicist from Lisbon, the final year of her undergraduate physics course had a class consisting of one man and seven women, a ratio which she says is typical!

Even in Britain, where women in science are more unusual, they are still quite confident about being feminine. A comparison of women undergraduates in physics with those in sociology[6], for instance, finds that the physicists are much more scientifically-minded than the sociologists, but that as far as femininity goes, the two groups were virtually indistinguishable. It's also noteworthy that nine out of ten women physics undergraduates look forward to having children[7].

Some Vital Statistics

The ratio of women to men, in undergraduate physics courses in British universities[2] is 1 to 8, and at postgraduate level slightly lower, 1 to 10. Women who have come so far in their scientific training are the lucky ones who have made the right choices at school, and have had the

chance to find out for themselves how attractive science can be. They will also have had some of the best training the country has to offer.

At this point, the statistics[2] produce a shock. In physics, while there is one woman postgraduate in physics to every ten men, at the professional level there is only one to every twenty. *Half* of the qualified women have disappeared!

Where Are All the Women?

For men who finish their training, and for a few women as well, what happens next can be discussed in terms of conventional career stages. For most women, however, what happens next will depend on what might be called life stages (for instance, marriage or childbearing) and the related life choices women make (that is, the relative weight given to these activities). Bearing in mind that the majority of women going into science intend to take part in family-centered activities such as marriage and child-rearing, it is important to consider the ways in which these interact with a woman's professional activity as a scientist.

The problems women meet when they enter the professional world, and even more when they try to combine professional commitments with those of home and family, are problems that go far beyond science into society as a whole. Two good books I have found on these subjects are the recent one by Glynis Breakwell, *The Quiet Rebel*[8], and an earlier study by Cynthia Epstein entitled *Woman's Place*[9]. Instead of discussing these more general considerations, we return to the Case of the Vanishing Scientists.

Half of the professionally trained women physicists vanish from the statistics. Where have they gone? One can make some reasonable guesses:

(i) A very few women will have chosen home and family as a full-time career. Their training should not be called 'wasted'. Their indirect input into society, by teaching and encouraging their children, and in other informal ways, can be vitally important, and their personal enrichment will be very real, even though it is not measured by a salary. Most women, however, do return to work.

(ii) They may be in the middle of a career break. *Most* women scientists get married and *most* women scientists have children. Moreover, most women scientists choose to step aside from full-time professional work at least while their children

are very young. Other breaks can happen as a result of moving from one place to another following the dictates of a partner's career. Not all women make my own choice that my husband's career would automatically take precedence over my own; but it is apparent that such breaks are still more common for women than for men.

(iii) The 'missing' women scientists, having taken a career break, may have entered another field on returning to work, either out of choice or because they couldn't find work in their own fields. There were three of us in Guildford at the same time, young mums with PhDs in physics and small children to look after. Although each of us is now a professional of one sort or another, I am the only one still in physics, and for me it was necessary to change fields. I suspect our experience is common.

(iv) Finally, there may be women who have made career breaks voluntarily, but who have not managed to find any professional employment afterwards. I do not know any personally, but I do know a quite brilliant scientist whose first job after her career break was that of an office cleaner! Obviously, a woman at this stage is not likely to know whether she will be able to make a successful comeback or not.

Aggravation and Hope

How does one come back to science? Each person's answers will be different, but I have a few suggestions. First of all, it is a great help to keep going in one's field even during a career break. Any sort of professional activity helps. There are always young people who need tutoring at 'O' and 'A' level. My own choices were writing abstracts for scientific papers, and doing correspondence tutoring for the Open University. It is also worth making the time to read magazines like *New Scientist* and *Scientific American*.

When one begins the return to professional activity, it is a great help to be flexible, and not to have too rigid a picture of what kind of work one will accept. My route back, for instance, took in six different jobs, from the teaching of CSE maths to postgraduate lecturing, before being given the chance to return to research in physics (thanks to an enlightened academic willing to take a chance on a woman part-timer from a different field).

Besides flexibility, one really needs to live near employment; and it

is also necessary to have adequate help to hand, even if it means financial sacrifice to pay for it.

Returning to industry is something I cannot comment on from my own experience. Returning to university science I can recommend as something to consider seriously. Academic work and family work are excellent complementary activities — each tends to enrich the other. Rachael, a metallurgist, calls doing university research 'an ideal job for a woman', and I have certainly found it so myself.

Women often want to begin work on a part-time basis, and a university environment lends itself to this way of working. Working hours can be very flexible, and working part time is not only possible, it is now being actively encouraged by such funding bodies as the SERC[10]. Part-time work is also quite an efficient way of working. Since one's hours are limited, there is a strong incentive to concentrate on the most important aspects of one's work. One can also bring to the work an intensity of effort which it would not be practical to sustain for full-time activities.

In university research, people are always being needed to work on new research grants and contracts. Moreover, different subjects keep coming up, so that if there are no suitable openings in the first year, there may well be one in the second or the third. But a year is a long time in science. It's not a very efficient use of the country's trained scientists if a number of them are forced into returning by circuitous routes which take several years even to get one to the starting point.

A new scheme just launched by Professor Daphne Jackson, President of the Women' Engineering Society, can make return altogether more straightforward. The scheme provides Fellowships for Women Returners[11], fellowships for periods of one-three years, part-time, in science and engineering, which will include the provision of research facilities and updated training. The scheme's long-term success depends on good applicants. That could well mean *you*.

The final stage worth comment is that of women who have returned successfully, and are employed on short-term research grants and contracts in universities. There are lots of them. Here, however, they are likely to get stuck. Funding cuts mean that there are few university positions available, and their age puts women applicants at a tactical disadvantage. The problems[12] are common to both men and women in these positions. But they are especially women's problems because this is where most women in university science are to be found. From five science departments[13] in the University of Surrey, for instance, there is one woman to every twenty men on the academic staff; for short-term researchers and academics, however, the ratio is 1

to 4. In the engineering faculty (which also employs scientists), the ratio is even more extreme: there are no women out of 116 academic staff, but again there is one woman to every four men, on the short-term academic and research staff.

These problems of short-term staff have not yet been tackled. But, while the career structure may be bad, the science one can do can be very good. Leila, a laser physicist, says 'It's not easy for us, but we manage'. Bridget (an electron microscopist) amends this: 'Tell them we don't just manage — we do very well!'.

Notes

1 Proverbs 8:30 (*New Jerusalem Bible* translation).
2 *Girls and Physics* (a report by the joint Physics Education Committee of The Royal Society and The Institute of Physics, December 1982) p. 1.
3 All names have been changed.
4 Ref. 2, p. 14. A study reported in KELLY, A. (Ed.) (1981) *The Missing Half*, Manchester, Manchester University Press, pp. 1, 22 and 73.
5 Ref. 2, p. 10.
6 WEINRICH-HASTE, H. and NEWTON, P. (Summer, 1983) in *Women in Engineering* (Equal Opportunities Commission Research Bulletin No. 7), table 10, p. 58.
7 *Ibid*, table 9, p. 54.
8 BREAKWELL, G.M. (1985), *The Quiet Rebel*, London, Century Publishing.
9 EPSTEIN C.F. (1971), *Woman's Place*, Berkeley, CA, University of California Press.
10 SERC circular 5/85 *SERC support of part-time and returning appointments in academic institutions*.
11 Further information is available from Professor Daphne Jackson, Dean of Faculty of Science, University of Surrey, Guildford, Surrey, GU2 5XH, tel. 0483 571281.
12 Some of these problems — lack of career structure, security, and university status — have been the subject of much discussion (see for instance the *Cambridge University Reporter*, 13 February 1985, p. 318ff). Other problems include lack of a firm base from which to build up a long-term program of research, or to attract associates.
13 These are the Departments of Physics, Mathematics, Chemistry, Microbiology, and Human Biology. Of the two remaining departments, the Robens Institute (health and safety-related problems) has no women to six men on the academic staff, and a ratio of 1 to 1, at short-term level. In Biochemistry (biochemistry, nutrition, food sciences, and toxicology) the ratio is exceptional: seventeen women to twenty-two men at academic staff level, and a ratio of 3 to 2, in short-term staff. Data courtesy of C.V. Jones and The Computing Unit, University of Surrey.

Part II
Gender Matters

7 *Brother Sun, Sister Moon: Does Rationality Overcome a Dualistic World View?*

Helen Weinreich-Haste

This article is about *metaphor*. It argues that human beings seem to have a deep-rooted tendency to construct dualistic categories of interpreting the world; this tendency appears to permeate all spheres of life, including science and technology and the human being's relationship with nature. It seems likely that if sex differences did not exist, we would have to invent them.

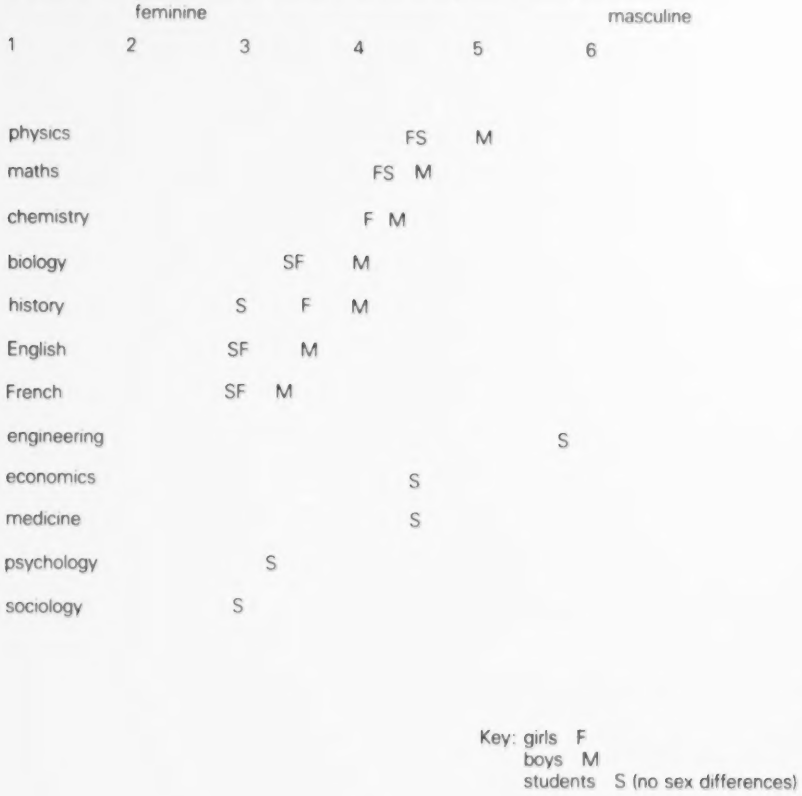
A few years ago I investigated the stereotypes of different fields of knowledge.[1] I asked schoolchildren and undergraduates to rate a range of subjects on a variety of scales (table 1 and figures 1 and 2). They identified certain subjects as definitely masculine, some as neutral, and *none* as definitely feminine. This is both interesting and depressing; such stereotypes indicate some of the problems that girls may face in

Table 1

Disciplines	Rating scales
English Literature	Hard — soft
Music	Masculine — feminine
Modern Languages	Science — arts
History	Complex — simple
Philosophy	Abstract — concrete
Cooking	Practical — theoretical
Sociology	Intellect based — feeling based
Political Science	
Psychology	
Economics	
Maths	
Medicine	
Biology	
Engineering	
Physics	

Figure 1 Relationships between Arts Science and Masculine Feminine dimensions (under-graduate sample)

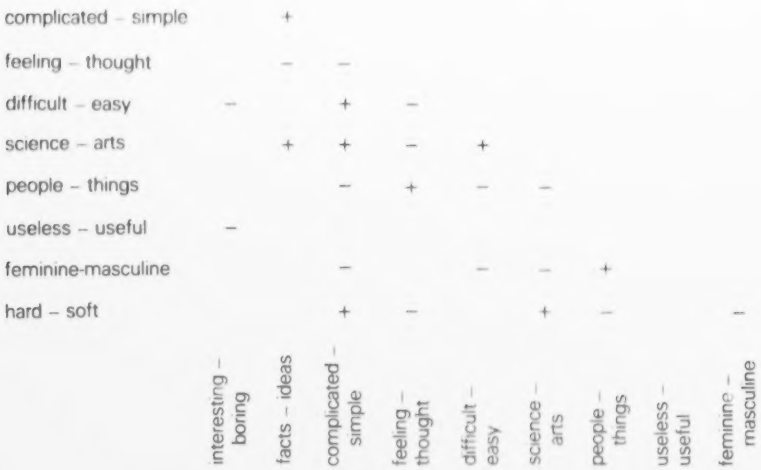
Figure 2: Masculinity and Femininity of Disciplines



choosing to do physics or maths. But even more interesting is the relationship between the masculine-feminine scale, and other adjectives (figure 3). There is clearly a *constellation* of beliefs about scientific subjects — they are hard, complex, based on thought rather than feeling, abstract and masculine. These clusters do not simply reflect the statistical probability that more boys than girls will choose science; they express a view of the fundamental masculinity of science, according to cultural stereotypes of 'masculinity'.

At the time I undertook that research, the questions people were asking concerned a pragmatic problem, how do we get more girls involved in science?. The resolution was seen to be in terms of educational policies which would raise teachers' consciousness about

Figure 3: Correlations between scales – school sample



possible discriminatory practice, undermine myths about sex differences in ability — or provide compensatory programmes — and increase girls' motivation.[2] But as people began to consider the issue more deeply, other questions emerged. Would science and technology be different if more women were involved? Were the sex differences more subtle than a matter of abilities? The deeper we delved, the more historical and anthropological evidence emerged which indicated that the issue of gender is part of a pervasive and fundamental *dualism*, a tendency to create frameworks for viewing the world in terms of bimodal categories, with attendant evaluations.[3] These categories are the basis of common-sense *explanations*, expressed in metaphor and folk-wisdom. A dualistic

description does not exist in isolation; it attracts justification and consistency. So women's greater passivity is not merely an observation; it is seen to serve some *purpose* in childcare or sexual relations. Evolutionary explanations are produced to explain its origin; biochemical evidence to analyze the mechanisms.[4]

Most strikingly, it became obvious that the dualism of gender mapped on to very basic beliefs about the relationship between the human being and *nature*. In so many areas, man's relationship with woman became revealed as metaphorically parallel to his relationship to his emotions, his spiritual life, and most significantly, his knowledge and understanding of the natural world.[5]

I will elaborate this by looking at three areas; the development of ideas about scientific method, beliefs about the characteristics of males and females, and the metaphors used by scientific writers in their description of scientific and technological advances.

Conventional definitions of 'scientific method' have their roots in the distinction made by Plato between *logos* and *pathos*, reason and emotion. This distinction was reaffirmed in the modern era by Descartes; scientific activity, or more particularly, the justification of that activity, is rational, untouched by emotion, analytical, objective, and involves the selection of variables deemed to be relevant, and the exclusion of the non-relevant. While recent thinking, as we shall see, questions this picture, it is the conventional image of science.

The history of gender imagery is complex, and there have been important changes at different periods. But consistently in Western culture women have been seen as more emotional, less rational, more intuitive, childlike and passive, and generally *closer to nature*. In mythic terms they have generally been associated with the moon and darkness. These gender dualisms are found in similar form in many cultures; even more significantly, attached to these polarities is an evaluation that the 'feminine' characteristics are less valuable, less understandable and less 'civilized' than the masculine. With the exception of two important periods, female sexuality has been seen as more demanding, less controllable and of greater power than males.[6] Sexuality is of course problematic for rational men; indeed as Easlea has pointed out, St. Augustine saw Adam's Fall as manifested in the loss of control over his sexuality. The two periods where this view of women's sexuality did not hold were firstly, the period of courtly love and chaste romance around the twelfth century, which also coincided with the beginning of the cult of the Virgin Mary — hitherto Christianity had been concerned solely with male figures — and the Victorian period. The elevation of female

chastity and purity had the effect of giving women status as beings of moral worth, the guardians of virtue and, at least in principle, potentially rational because free of desire.

The third set of images links the first two. The primary image of scientific endeavour which recurs throughout the modern period is of Nature, as female, being conquered, penetrated and yielding up her mysteries to the male scientist (table 2). Note that as well as the obvious sexual symbolism of these images and metaphors, the relationship implies control, domination and the imposition of order and reason.

Table 2

Francis Bacon
- 'nature to be commended must be obeyed'
- (the scientific method) 'allows man to penetrate into the inner soul and further recesses of Nature'
- by art and the hand of man she is to be forced out of her natural state, and squeezed and moulded (to yield) the many secrets of excellent use'
- (Aristotle left) 'Nature herself untouched and inviolate (being unwilling) to lay hold of her and capture her'
- (a mistake to assume that men were) 'on such familiar terms with Nature that, in response to a casual and perfunctory salutation, she would condescend to unveil to us her mysteries and bestow on us her blessings'

Barrow (Newton's teacher)
(aim of new philosophy) 'search Nature out of her concealments, and unfold her dark mysteries'

Glanvill (seventeenth century)
> And yet this is a miserable disorder into which we are lapsed. The woman in us, still prosecutes a deceit, like that begun in the garden; and our understandings are wedded to an Eve. ... And while all things are judged according to their suitableness, or disagreement to the Gusto of the Fond Feminine, we shall be as far from the Tree of Knowledge, as from that which is guarded by the Cherubim. ... (the goal of experimental philosophy is) the ways of captivating nature and making her subserve our purposes. (quoted in Easlea, *Science and Sexual Oppression*)

Such metaphors are paradoxical. Quite apart from the genuine involvement of some women in the development of science and technology of the 'official' sort, there were whole areas in which women's 'closeness to nature' was a consequence of her actual greater understanding of such natural processes as the use of herbal remedies for healing. As innumerable writers have pointed out, as medicine became more professionalized and in the hands of male doctors, the very real knowledge of the 'wisewomen' became lost as it was

denigrated and stigmatized as magic, sorcery or mere mumbo-jumbo.[7]

The growth of technology produced metaphors on similar lines, except that whereas science — if one can make a crude and over-simplified distinction — is about the control of *knowledge* about the world, technological advance gives human beings the power to *alter* the world. So the scientist gains an enriching *access*, but technology may be used in ways that create alienation between the human being and the natural world — the dark satanic mills in England's green and pleasant land. Apart from the obvious — and explicitly used — analogies between 'tools and utensils' and gender metaphors, technological progress gave rise to other symbols. Henry Adams, for example, explored the metaphor of the dynamo and the Virgin; by the beginning of the twentieth century, he argued, the symbol of energy and infinity had become the dynamo and the powerhouse, replacing the Church and the Virgin as symbols of the life force and of nature-based spirit.[8]

This review of historical analogy and metaphor shows how the dualism of gender has been inextricably mapped on to the dualisms of man *versus* nature, reason *versus* passion, controlled *versus* uncontrolled, and logical *versus* intuitive. These dichotomies concern ways of understanding the world, methods of dealing with experience, and acceptable ways of creating explanation for events. They are obviously extremely pervasive — so pervasive that I want to ask what would be the effect of removing the gender dualism from the overall cosmology? If we are experiencing a change in the gender metaphors of the sort which will allow women greater participation in science and technology, are we also in the midst of a necessarily changing conception of the relationship between the human being and Nature, and a changing conception of how we should attempt to understand the natural world?

Feminism, at various points in history when it has emerged as a dominant force in social thought, has never been confined solely to the demand for legal changes; it has always been associated with efforts to change the conception of sex roles and sex differences. Partly this is a logical and pragmatic problem; if women are believed to be lacking in certain abilities which are seen as necessary to perform certain tasks, then it is necessary to counter the beliefs either that there are such sex differences, or that the task in question requires those abilities. But such changes in conception are not only a matter of fact; as we have already seen, there is a marked tendency for qualities associated with the female to be given less value, and less credibility, than those associated

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with the male — or else to be partitioned off as 'mysterious', inaccessible to the dominant mode of rational thought.[9] To change such evaluation requires more alteration of perspective than is required to undermine a factual beliefs.

An example of this process comes from the rise of feminism in the United States. In the mid-nineteenth century feminism was part of a *moral* crusade; once it came to be believed that women were less accursed with the sinful and irrational lusts of the flesh, it was an easy progression to seeing them as the guardians of morality, keeping men's baser natures under control. Feminism was associated at that time with humanitarian campaigns such as anti-slavery, and with moralizing campaigns like temperance and the control of prostitution, though there were a few libertarian feminists who advocated free love. Indeed, so strong was this moral image that apparently it was not the liberal Eastern states who first introduced women's suffrage, but Wyoming, a rumbustious frontier land anxious to improve its image as a moral, civilized place.[10]

In that case, the changing view of gender involved developing an evaluation of women as morally superior — the inversion of a sex difference and its evaluation. There are perhaps three ways in which the dualism of gender can be undermined: by the *denial* of sex differences — the denial of dualism; by the *redefinition* of dualism as a dialectical integration — like the Eastern concept of yin and yang, and the concept of androgyny as the presence within all individuals of both masculine and feminine qualities; and by the affirmation of a dualistic perspective but with a *re-evaluation* of the polarities. The present wave of feminist thought has at different times used all three approaches.

First, there has been a considerable amount of research, especially in psychology, to investigate the extent of sex differences. The consequence has largely been to establish that most supposed differences either do not stand up to scrutiny, or else are the product of socialization, and therefore malleable.[11] According to such a conclusion, there should be no bar to women's or men's participation in all fields of life. Furthermore, there should be no consequences for the nature of a field as a result of changing balance of male or female participation.

Second, the development of a concept of androgyny owes much to the formulation of dualisms such as instrumental v. expressive and agency v. communion, which are not strictly *antitheses* but represent different ways of approaching experience. They do not represent either-or categories, and it is apparent to many people that effectiveness —

whether in an activity or as a rounded personality — depends on some balance between these. Within psychology the concept derived mainly from the work of Bem, and Spence and Helmreich, who devized personality measures on which the individual could score high or low on *both* masculinity *and* femininity, thus ending up with a score of being either sex-typed or androgynous. It was found that androgynous people, who scored high on *both* masculinity and femininity, were generally healthier, and more adaptable, than sex-typed people.[12]

The conclusion from these studies is the general appreciation that a balance of the two modes is more valuable than polarization, that people can — or should — be able to switch into the desired mode as required, and that having only one set of resources is limiting. Hence, the woman entering science will need to make more use of her instrumental, agentic potential, the man entering the caring professions, of his expressive, communionalistic potential — but the other pole is not irrelevant to either job. Androgyny therefore seems the best of all worlds; it allows the existence of masculine and feminine principles, but removes the dichotomous and incompatible aspect of the duality.

Unfortunately there still remains the lingering cloud of cultural stigma. While people are happy to allow women a more instrumental dimension provided they also retain some 'femininity', the reverse is not always the case. There remains much resistance, and ridicule, attached to men becoming more expressive, more feminine. A few years ago I presented girls with a story of Julie the trainee engineer, and boys with a story of Dave the trainee nurse, and asked them to continue the narrative. For the girls there was no difficulty; Julie could expect objections from parents and possibly friends, but she was determined and went on with her course, proving that she could do it; even her boyfriend supported her. Dave, on the other hand, caused great anxiety to the boys; he had bizarre accidents, and most frequently, he was explicitly seen as suffering various sexual difficulties.[13]

The concept of androgyny, and the recognition of its value, is nothing new in the arts. Yet even there, historically there was resistance.[14] Rupert Brooke, upholder of the hero ethic in the First World War wrote 'This mixing of the sexes is all wrong: male is male and female is female ... manliness is the one hope of the world'. Manliness, indeed, was perceived as the hope of the world by many, from Baden-Powell to the eugenicists and the technologists with their image of the dynamic powerhouse. Brooke was reacting to an Edwardian move towards a new androgyny, particularly associated with the Bloomsbury group. Virginia Woolf described some of the 'manly'

writers like Kipling and Galsworthy. 'The emotions with which these books are permeated are to a woman incomprehensible. One blushes . . . as if one had been caught eavesdropping at some purely masculine orgy.'[15] Note that Virginia Woolf and others did not retreat into writing Mills and Boon romances, but to writing works which *integrated* the masculine and the feminine, the expressive and the instrumental — most explicitly, of course, *Orlando*.[16]

The third response to dualism is to re-evaluate the dichotomy and to redefine the polarities. This has something in common with the nineteenth-century elevation of women's superior morality, except that it does not affirm a superiority, merely a *validly distinct* point of view for each sex. This distinctiveness comes, some argue, from the differences in experience between the sexes. There is nothing new in the recognition that child-bearing or suckling — and their anticipation — may have some influence on women's view of life, but recently a sociologist, Chodorow, has proposed a far-reaching model. She argues that the differences arise in early childhood. Both sexes, in most cultures, are reared initially in close contact with a female caregiver; this is an early bonding and symbiotic relationship. For girls, this early experience is with a *similar* creature, and the distillation of experience is through and with someone who is *connected*, by this similarity, to the self. This does not change; as the girl grows, her similarity to the mother-figure increases, consonantly.

For boys, however, there soon comes a point when there must be a recognition of difference, of separateness, of *otherness*. This, argues Chodorow, leads the boy to see the world as something from which he is *apart*, not connected, and even in conflict.[17]

The consequence of these differences is both affective and cognitive; it lays the foundation for a way of looking at the world, and interpreting all experience, so the girl grows up *embedded, connected* and *in harmony*, as a basic framework for relating to people and things, whereas the boy grows up *unconnected, separate* and expecting to negotiate from a *position of otherness*, even of conflict. Of itself, such a model might be seen to put too much explanatory power on to a brief period of early life, but it must be seen in the context of the kinds of social representations of the world which boys and girls encounter; of women as rooted in nature and in tune with emotional life, and men as separate from nature, struggling for mastery and control, and proving themselves in conflict. Seen thus, and it acquires a more social and cultural dimension.

The implications of this reinterpretation of dualism are that there are different *ways of knowing* associated with masculinity and feminini-

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ty — though not necessarily tied to actual maleness and femaleness — and that these should be recognized for their distinctiveness. The approach aims to investigate more fully what is implied by this difference; the implications for science and technology are that there would be differences in how scientific activity is conceived, and how the products of science and technology are evaluated. It is, in effect, *a new form of rationality* in complement to the traditional form, but *not* an evaluation of emotion v. reason *per se*.

I shall now explore some of the recent changes which have taken place in our views of science, not solely as a consequence of the development of feminism, but contemporaneously in parallel with it. There are three examples I want to consider. The first concerns the *moral reaction* to scientific and technological advances. The second concerns the increasing number of studies of how scientific activity is *really conducted*, and the gap between this and the rhetoric of justification. The third concerns the development of alternative *ways of knowing*, and their application to scientific and technological research methods.

'Moral criticisms' of scientific and technological advance have always existed, but recently they appear to have increased. Partly of course this is because of the genuine power of scientific knowledge and the increased possibility of cataclysmic accident. As a result, more people feel personally threatened, and more willing to question what goes on in science. The nuclear threat has recently been slightly eclipsed by the genetic engineering debates — conspicuously involving 'moral experts' such as philosophers and politicians, rather than only scientific experts.* I will consider two forms of moral criticism.

The first includes both 'anti-science' and 'alternative science'. There are many important differences between these two, but they have in common a rejection of 'high tech,' a 'back to nature' ethos, and most strongly, a rejection of the model of control and domination which they see as a fundamental principle of scientific activity, which has yet got out of control. In response to the alienation of the human being and nature, nature has (or will) fight back against the devilish contrivances, reassert the life force over the dynamo. While the anti-science group reject science, and the alternative scientists try to find a rational alternative to high tech, both are, I think, seeking a new metaphor for the human being's relations with nature, involving harmony, and working with, rather than conquering, natural forces.[18]

The second criticism does not consider the high tech model, nor

*Though Chernobyl has revived concern about nuclear energy.

does it necessarily question the control-domination metaphor; it is instead a critique of the narrow vision of those scientists and technologists who focus only on the academic problem and ignore the consequences and implications. This is partly an ethical consideration that researchers should take moral responsibility for their work. But it is also a plea for a more holistic approach, that scientists should not consider it *conceptually*, let alone morally, justifiable to shut themselves off in the 'pure' world, ignoring the applied. The field of nuclear weapons research is an obvious one, and there are many examples from it; in Robert Jungk's account of the Manhattan Project is the description of the different ways — and the different speeds at which it happened — that individual scientists began to confront the wider implications of what they were doing. At the beginning, people were able to consider the 'beautiful physics'; by the end, no-one would have been able to constrain their thinking only to that aspect. Latterly, there has been a significant shift in thinking some people do not think only of the 'possible environmental effects' but actually are beginning to conceive of what they are doing within an ecosystem.[19]

But perhaps even more wide ranging has been the questioning of received wisdom about how science is 'done'. Every working scientist knows how messy the real-life world of research is, but the convention has remained that one presents research findings as if they conform to the Cartesian process of logic, analytical thought and the linear deduction from careful observations. This normative model of the scientific process received its first dent from Kuhn's demonstration that paradigm made a difference to how one interpreted one's findings, and the role in scientific development of noticing the anomaly and taking it seriously. In the following decades, many philosophers and sociologists of science have analyzed in detail the way that scientists work.[20] A notable example is Ian Mitroff, who investigated Apollo Moon scientists. He identified two types of scientist. The first, who conformed to the normative image, was cool, rational, logical and systematic. The second, the counter-normative scientist, recognized the importance of commitment, intuition and heuristic guesswork, and speculation. The latter group regarded the former as essentially technicians, and the latter type had greater prestige amongst their peers. Such accounts undermine not only the *image* but also the *value* of passionless objective neutrality — as also do the accounts of individual scientists such as Watson's *Double Helix*. Innovation clearly requires risk-taking, and risk-takers tend not to be bound by the constraints of convergent thought.[21]

So the Cartesian dualism of reason and passion is undermined by

looking at the real world of problem-solving. It would be helpful at this point to consider what it was that Descartes opposed. On the one hand he contrasted reason and passion as effective means of arriving at truth, but in addition he was in conflict with a group of philosophers whose ideas are currently re-emerging in a different form. These were the Humanists, whose argument in essence was that we do not gain knowledge through logic but through an appreciation (or what we would now term an apperception) of meaning. This we gain through *metaphor*, *imagery*, and *analogy*. While we may choose to express our understanding in terms of logic, our insights do not come that way; also, we cannot effectively communicate ideas to others by logic but by a metaphoric process which allows the other the insight. Whether Descartes' model of logical knowing, or the Humanists' model of metaphoric knowing, is 'better' in any particular situation is a matter for experimentation and debate, but the important point is that the original disputes seem not to have been between 'rational' knowing and 'irrational' knowing, but between different routes to rational knowing. And the increasingly available evidence of how innovative solutions are arrived at does strongly suggest the importance of metaphor and imagery — 'non-logical' insight — in that process.[22]

Thus far I have considered two aspects of the pervasive dualism which maps onto gender within commonsense imagery: *reason v. passion*, and *rationality v. intuition*. A third duality is *atomistic v. holistic*. As such, this duality is not necessarily gender-linked, but as I will show, some of its implications are. One of the consequences of a logical-rational, control-oriented approach is a tendency to atomism, to reducing the problem to isolated variables, linear focussing by deduction, and the exclusion of the 'non-relevant'. The assumption is that by this process one eliminates value and the intrusion of distracting detail. In fact, of course, the selection-out process itself must make massive assumptions. Piaget argued for a more holistic approach to objectivity (figure 4). In other words, 'objectivity' involves a holistic *inclusion* of what might be relevant and salient, not an arbitrary *exclusion*. A more effective approach to knowledge and rationality is gained if we start off with a model of inclusion rather than exclusion, but such an approach requires a different way of dealing with data and its interpretation; it does not, for example, allow for the imposition of a pre-existing schema, and controlling framework, onto the material. I earlier considered another aspect of holism, namely the recognition that a problem exists as part of an ecosystem, and understanding or resolving the problem involves considering the wider issues.

I will briefly consider two studies of women scientists which make

Figure 4

Piaget on objectivity

Objectivity consists in fully realising the countless intrusions of the self in everyday thought and the countless illusions which result — illusions of sense, language, point of view, value etcetera — that the preliminary step to every judgement is the effort to exclude the intrusive self. Realism, on the contrary, consists in ignoring the existence of self and thence regarding one's own perspective as immediately objective and absolute. Realism is thus anthropocentric illusion and finality — in short — all those illusions which teem in the history of science. So long as thought has not become conscious self-it is prey to perpetual confusions between objective and subjective, between the real and the ostensible.

The Child's Conception of the World

points about different aspects of holism. The first is Lillian Moller Gilbreth, whose biographer is Martha Trescott.[23] Apart from having twelve children, for which she was in the popular mind most known until recently, she worked with her husband Frank Gilbreth in the field of management and engineering. He in fact died relatively young, and she continued the work for several more decades. The framework within which they initially worked was Taylor's scientific management, or time and motion study. Lilliam Moller Gilbreth brought to this work a broader perspective than the narrowly mechanistic concern with physical action, looking at the worker in the psychological situation, in other words, she took into account a more eclectic perception of the problem.

The other scientist, Barbara McClintock, is discussed elsewhere in this volume by her biographer, Evelyn Fox Keller. In *A Feeling for the Organism*[24] Evelyn Fox Keller shows how Barbara McClintock's style of working and of thinking went counter to the accepted way of 'doing' biological science. She engaged in immensely detailed and careful observation, not to quantify or count, but to *understand*. She had respect for insight and for the non-conscious processes of the mind; these may *later* be turned into a logical account, but they occur best when one is *in tune* with the organism or objects under investigation. She trusted her intuitions, and worked through careful intimate appreciation of her material; this method led her to reject the elegant simplicities of the molecular biology of the time, and to appreciate the complexity of the processes she was studying.

Does it matter that these two scientists were women? So far I have drawn together material from a wide range of sources — albeit all of it very brief and sketchy, and little more than passing illustrative — to argue that there is a parallel between certain developments in science and technology, and the deep-rooted dualism of gender that our culture accepts as a framework for metaphor, and even, in some cases, for

explanation. I have tried to argue that we can now recognize the pervasive model of 'masculine' science, kept alive in principle by the rhetoric of justification even if it is not an accurate reflection of what goes on. In contrast to that pervasive model, one can see many versions of critique, objection and antithesis, and views of science that say not only 'this isn't how things are' but also 'this isn't how things should be'. Some of these prescriptive objections are on moral grounds; others are on the grounds that it just isn't *effective* to do science this way. Few of the critics, apart from feminists, couch their objections in terms of making science more 'feminine'; they take the other pole of the dichotomy — whatever it is — and justify it. But it happens, I have argued, that these other poles do tend to match the 'feminine' end of the gender duality. Is that merely a semantic accident, or is there something more deep-rooted?

It is obvious even from my brief review that it is not only women who do 'feminine' science in the way I have — by default — defined it. One could certainly argue that what characterizes those who question the orthodoxy is that they are — or become — marginalized, and marginal people tend to see things from a different perspective. Women have always been marginal in science, and this may both free them from the tyranny of the orthodoxy, and allow them the scope to develop alternative methods, if they have the confidence, luck, or bloody-mindedness to persevere. This is true of marginal men also, and it seems fairly clear that such are the people who do innovate, in all fields. But let me finally explore the available evidence for the sort of sex differences which might predispose women to another *way of knowing*.

It seems to me that the key issue is the process by which a problem is tackled, and the dimension seems to be linear-analytic *versus* eclectic-holistic — or, in crude physiological metaphor, going for the jugular v. taking the organism as a whole. This is clearly a *cognitive style*, and is therefore likely to be perceived across different areas of experience, not confined to science. To explore this I will look at two areas of research on sex differences; both of these I have referred to already in passing.

The first is research by Witkin on what he called 'field independence'.[25] Basically this means the extent to which the individual can ignore, or dissociate from, misleading or distracting cues. In one measure, the individual has to align a rod to the vertical against a background of a tilted frame; in another, the individual has to identify a figure which has been 'embedded' within another figure — a sophisticated version of the children's comic game 'how many cats can you see hidden in the tree?' Boys, on average, are better at this than girls; additionally, boys with over-protective mothers do less well than boys

trained in independence, and both sexes of Eskimos — who live in a featureless waste which gives them few useful alignment cues — are better than forest-dwelling peoples. Clearly, therefore, it is not a strongly physiologically-based difference; it may have some relationship with child-rearing methods, and with the external demands of the environment on perceptual processes. There are two interesting aspects of this research for the present argument. The first is that it is assumed that boys are 'superior' — that field independence is 'better' than field dependence, in line with the 'linear logic, ignoring the irrelevancies', model. The second is that when the actual scanning process is observed, males spend more time focussing on the target, and at the same time make more shifts between the target figure and alternatives; furthermore, the longer time they spend, the more the shift and the *worse* their performance. Females spend more time generally on the items, but less on the target figure. These findings are consistent with the view that females are more willing to take in the whole field and less willing to select out and focus on one aspect of it.

The second is research recently emerging from the literature on the development of moral reasoning, by Carol Gilligan. This type of research is complex, and involves the analysis of responses to moral dilemmas in terms of the kind of reasoning used. The original, path-breaking research on the development of moral reasoning was done by Kohlberg, who identified developmental changes in the reasoning of boys, which concentrated particularly on their understanding of rights, fairness and justice. Gilligan found that although girls could talk in these terms, they tended to focus on the moral issue of responsibility and caring. So whereas the boys were likely to see a moral dilemma in terms of a conflict of rights between persons, girls tended to see it in terms of responsibilities between the actors; negotiation of who should care for the victim, rather than a discussion of who had more claim to rights. She argues that this reflects a difference that boys tend to see the situation as involving *separate persons in conflict*, whereas girls see it as persons *embedded in mutual relationships*. She has utilized Chodorow's model, which I described earlier, of the development of *connectedness and similarity* in girls, and *separatedness* in boys, to argue that the predominant cognitive style and way of interpreting experience is laid down early.[26]

Both these studies are about cognition, and about methods for processing information and solving of problems. Neither suggests that females are *less* rational, but both suggest a different approach to rationality. For the male, it is a tendency towards exclusion focussing and linear logic; for the female, it is a tendency towards inclusion, broad

scanning and synthesizing rather than analyzing. Now, we must be very careful about seeing these as actual *sex* differences; many girls were field-independent on Witkin's task, and many boys field-dependent, and there were girls in Gilligan's study who talked in terms of a conflict of rights, and boys who had a responsibility orientation. But what seems to be emerging tentatively from these studies is the possibility of identifying two *styles* of dealing with the world — whether it is advanced scientific work or the resolution of adolescents' moral crises — which do not fit the model of 'rational v. irrational' or 'reasoned v. passioned', but which at the same time do have something of the gender-related pattern metaphorically and conventionally associated with those dichotomies. In many ways this is a re-emergence of Hudson's distinction between convergent and divergent thought, but with a much more extensive picture of the range of processes involved.[27]

So, finally, how do I answer my earlier question; does it matter that Lillian Moller Gilbreth and Barbara McClintock were women; and also the much broader question of whether science would change if there were more women doing it? The answer must be speculative, and to exercise a well-worn cliché, more research is needed — on the thinking of top women (and men) scientists, and on the *details* of sex differences in complex problem-solving behaviour. But what seems to me to be a fair conclusion is that:

(i) the pressures for certain conventional views of what *does* and *should* constitute 'science' have been narrowly and consistently defined within a particular model of rationality;

(ii) this model of rationality has for at least one, if not two, millenia been inextricably tied up with a wide-ranging dualism which has provided a framework for Man (sic) to make sense of his uneasy relationship with nature, his own irrational potential, and womanhood;

(iii) gradually, and perhaps because we now do have a terrifying power over certain aspects of nature, there is emerging an alternative conception of rationality which is more holistic and less control-oriented; because of the deep-rooted dualism, this development has been mapped onto the gender dichotomy, and exceptional women like Gilbreth and McClintock provide symbolic models of another way of knowing.

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8 *The Masculine Image of Science with Special Reference to Physics: How Much does Gender Really Matter?*

Brian Easlea

> Philosophy, I say, and call it, He,
> For whatso'ere the Painters Fancy be,
> It a Male-virtue seemes to me.
> Abraham Cowley, *Ode to the Royal Society*

> The struggling for knowledge hath a pleasure in it like that of wrestling with a fine woman. (George Savile, Marquess of Halifax)

The Maleness of Science

As in the case of many other activities in the public domain in Britain and the United States, the sciences, especially the physical sciences, are overwhelmingly male-dominated. One of the most male-dominated of the sciences is physics. In Britain, for example, the 1982 membership of women in the Institute of Physics was under 5 per cent while in the United States women held only eighty out of some 4200 faculty positions in 171 doctorate-awarding physics departments. Although chemistry, and particularly biology, have a higher female representation, women are still very much a minority in the sciences, constituting in the United States, for example, only some 12 per cent of all scientists and engineers.[1]

The male domination of science is, of course, related to the overall problem of patriarchy. Certainly during much of the existence of modern science women were legally and explicitly excluded from its institutions. However, although such legal barriers have now been dismantled in Britain and the United States, women continue to remain

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underrepresented in the sciences. Moreover, for example, even at school level in England and Wales male predominance in the physical sciences, and particularly in physics, continues to exist as a 1982 Report of the Physics Education Committee, set up jointly by the Royal Society and the Institute of Physics, makes abundantly clear. Thus the Report states that during 1978–79 only 0.32 girls to every boy attempted an 'O' level in physics although the corresponding figure was 1.69 for biology. More optimistically, the Committee concluded on the basis of other comparisons that once girls have gone beyond 'O' level in physics their success rate is such that 'the position in physics, relative to other subjects, does not get appreciably worse at higher levels of the system'.[2] A basic problem the Report therefore identifies is to understand why so few girls take physics even to CSE and 'O' level stage.

The members of the Committee suggested many possible reasons but they gave particular emphasis to what was called the 'masculine image of science'. This is because, as the Report stresses, if achievement in science is regarded as having a masculine image then not only parents and teachers may regard scientific ambition as inappropriate for girls but also girls themselves may see achievement in science as incompatible with their developing femininity. It is, moreover, the Committee's opinion that there can be little doubt that science is generally regarded as a masculine activity and physics as particularly so. In the case of the latter, the Report suggests, the strongly masculine image reflects a variety of factors, in particular the obvious male domination of physics, the direct links of physics with what are widely regarded as masculine spheres of activity such as industry, military and space, and the remoteness from concern with living beings which the Committee sees as characteristic of physics.

What I wish to do in this contribution is to try to enumerate and explore various aspects of the masculine image of science and the strongly masculine image of physics. I will be concerned in an overall way not only with what constitutes masculinity in the self-images of physicists, the public image of physics, and schoolchildren's images of physics but also with what reality, if any, lies behind these images and what might be the more important implications of a masculine character to science in general and physics in particular.

The Masculinity of Science

First a brief word on definitions. By 'male' and 'female' I refer to biological characteristics, by 'masculine' I mean those psychological and

behavioural characteristics that are widely supposed to be possessed or displayed predominantly by men, and by 'feminine' those psychological and behavioural characteristics that are widely thought to be possessed or displayed predominantly by women. I am not, of course, supposing that so-called 'masculine' qualities cannot be possessed or displayed by women and so-called 'feminine' ones by men. In British and American culture it would appear that, *very crudely speaking*, such qualities as aggressiveness, hardness, 'disconnectedness', self-control and emotional reticence have been widely seen to be qualities either to a considerable extent possessed by most men or which ideally ought to be possessed by men, and qualities such as submissiveness, softness, connectedness, receptivity and the capacity to nurture as qualities possessed to a considerable extent by most women or which ideally ought to be possessed by women.[3] It may be noted that men and women who in no way conform to such cultural expectations are no threat to stereotypes, nor, generally speaking, are a few individuals of the 'wrong' sex in any predominantly one-sexed institution, even if they occupy commanding positions.[4]

Why, then, does science have a masculine and physics a strongly masculine image? It is surely not simply a consequence of the fact that science has historically been an activity undertaken almost exclusively by men. Indeed, in a discussion of the genderization of science Sandra Harding refers to studies which claim that science is very widely seen, both now and in its origins, as being 'more closely tied to characteristics thought to be disproportionately distributed to men' than is the case for such male-dominated activities as art, law, government, wealth creation and even the making of war.[5] Thus from this viewpoint physics is widely perceived to be strongly masculine not so much because it is one of the most male-dominated of the sciences but rather because it is widely believed that physics can be successfully pursued only by *male* human beings and, moreover, only by men possessing certain strongly masculine qualities. What might these strongly masculine qualities be?

Aggressive, Competitive Behaviour

In her study of the prestigious and influential international high-energy physics community, of which women apparently constitute only some 3 per cent, the anthropologist Sharon Traweek claims that predominant traits manifested by European and American members of this exclusive community are those of 'aggressive individualism, haughty self-confidence, and a sharp competitive edge' and she asserts that these

traits are typically defined by our society as masculine ones.[6] I suspect that neither of these claims will be seen as particularly controversial. Nevertheless, even if we grant that such abrasive masculine qualities are widely believed to characterize high-energy physicists in particular and even believed to characterize physicists in general, this fact alone would not be sufficient to explain why physics rather than biology is supposedly seen as a strongly masculine discipline. For traits such as aggressive individualism and a sharp competitive edge are presumably also widely perceived to be important for success in a supposedly less masculine science such as biology, as well as in masculine activities outside the scientific arena. Indeed, in his popular book *The Cosmic Code* the high-energy physicist Heinz Pagels tells readers that 'a predominant feature in the conduct of scientific research is intellectual aggression' and that 'a healthy sense of ego and intellectual intolerance is crucial to the conduct of enquiry'. Claiming that no great scientific discovery was ever made in the spirit of humility, Pagels states that the successful scientist necessarily enjoys a 'one-to-one ratio of ambition to ability'.[7] Likewise the distinguished biologist Richard Lewontin agrees that the requirement for great success in science is great ambition and baldly asserts that science is a 'form of competitive and aggressive activity, a contest of man against man that provides knowledge as a side product'; moreover, it is clear that Lewontin does not exclude biology from such a relatively harsh appraisal.[8] It would thus appear that however important aggressive, competitive behaviour is for reaching prominence in physics and however important such behaviour is widely perceived to be, it is therefore unlikely that physics would be widely perceived as unique in this requirement and hence a public perception of pronounced aggressive competitiveness in physicists could not by itself account for a strongly masculine image of physics. Nevertheless, it is surely an important ingredient of that image.

Remoteness from Concern with Living Beings

To the extent that culture associates men (and not women) with competence in the design and control of apparatus and machines and associates women (and not men) with competence in professions demanding the capacity to care and nurture, it is not surprising that the practice of physics is associated with a masculine ability to manipulate and control inanimate matter rather than with a feminine ability to empathize, communicate and care. As a consequence, the discipline of physics may come to be embraced by many schoolboys and rejected by

many schoolgirls as one of the sciences furthest removed from a stereotypically feminine realm of relating empathically and caringly to other human beings. Obviously, this is a crude and global observation but I am sure that the Physics Education Committee's claim is at least plausible that apparent remoteness from concern with living beings is one important aspect of the masculine image of physics which is missing in the images of supposedly less masculine sciences such as biology, medicine and sociology. As Esther Saraga and Dorothy Griffiths affirm: 'Biology . . . . with its concern for living things, appears more personal and alive, and closer to the everyday world of values and emotion, which women are expected to inhabit. Choosing the biological as opposed to the physical sciences thus involves girls in fewer contradictions and they receive more encouragement and support in their choice'.[9]

Scientific Method

Also contributing very importantly to the masculine image of physics is, I suspect, a widespread belief in the existence of a scientific method which physicists, because of their own special masculine qualities and the nature of their subject matter, are adjudged ideally equipped to pursue. For example, of long standing is the belief that successful practitioners of scientific method must ruthlessly suppress all extraneous factors, particularly intrusions of an emotional kind, and so allow themselves to be guided by logic and facts alone in order to arrive at their (assumed) goal of genuine knowledge and truth about nature. Thus in 1913 Bertrand Russell could write that 'the scientific attitude of mind involves a sweeping away of all other desires in the interests of the desire to know — it involves the suppression of hopes and fears, loves and hates, and the whole subjective, emotional life'; in 1939 the historian E.H. Carr would approvingly refer to 'that hard, ruthless analysis of reality which is the hallmark of science'.[10] I suspect that E.H. Carr has hit the nail on the head! Such 'hard, ruthless analysis of reality' exemplified by suppression of all emotion, speculation and wishful thinking undoubtedly constitutes for many people the hallmark of scientific enquiry and thus greatly contributes to science's overall masculine image. The special masculine aura of physics no doubt reflects the belief that the subject matter studied by physicists, unlike that of biologists, can be subjected to both rigorous experimental and mathematical investigation and, moreover, that physicists have

achieved their spectacular successes by possessing the hard-nosed, mathematical mental endowments so necessary for successful pursuit of their discipline. Given, then, such a view of scientific method, it follows that to the extent women are culturally believed to be less mathematically capable then men, less able to control their emotions, and generally more adept in 'intuition' than in 'logic and reason', then the requirements of scientific method seemingly dictate that of those women who do enter the male preserve of science only a very small number possessing specially 'masculine' qualities will be able to achieve advances accessible in principle to many or most of their male peers. Thus of the distinguished astrophysicist Cecilia Payne-Gaposchkin, Edwin Hubble once remarked that she was 'the best man at Harvard'.[11] Such a view of the specially strong masculine, non-feminine personality and endowments of scientists has certainly had a long currency. The physicist and biographer of Newton, Sir David Brewster, wrote in 1844 that 'the mould in which Providence has cast the female mind, does not present to us those rough phases of masculine strength which can sound depths, and grasp syllogisms, and cross-examine nature'.[12] In his celebrated 1874 survey of English men of science, Charles Darwin's cousin, Francis Galton, pronounced that the 'man of science is deficient on the purely emotional element [and that] in many regards the character of scientific men is strongly anti-feminine; their mind is directed to facts and abstract theories, and not to persons or human interests . . . they have little sympathy with female ways of thought'.[13] One could give examples almost indefinitely.

The perception of scientific method is the crucial feature here. For if boys rather than girls are encouraged and expected to be emotionally reticent and if scientific enquiry is perceived as a necessarily unemotional activity in which the exercise of intuition and artistic creativity will have only negative effects, then it follows that 'unemotional' boys rather than 'emotional' girls will be encouraged and drawn to study science at school. For example, according to the educationalist John Head, 'male scientists, both science students and mature, professional scientists, tend to be emotionally reticent, disliking overt emotional expression in others and themselves' although, interestingly, he also states that those girls who do study science 'are not particularly emotionally reticent or rigid in their thinking'.[14]

Of course, it is quite untrue that scientific advance depends on the ruthless suppression of all non-logical and non-factual inputs to scientific enquiry, as has become clear following the debate initiated by Thomas Kuhn with the publication in 1962 of his famous essay *The Structure of Scientific Revolutions*.[15] As a consequence of this debate it

is clear that since logic and experimental evidence do not even in physics uniquely determine a scientific theory and even less the physical interpretation of a mathematically formulated theory, successful scientific enquiry necessarily depends on the contribution of all kinds of scientists whom we might call 'convergers' and 'normal scientists', 'divergers' and 'revolutionary scientists'.[16] Thus while Heinz Pagels insists in his popular book that intellectual aggression is necessarily a predominant feature of scientific research he also argues that the successful theoretical physicist must not only be highly trained in mathematics but must have 'good physical intuition' – indeed, Pagels stresses that the role of 'intuition and imagination' in the sciences is absolutely essential.[17] Perception, then, of scientific method is one thing, 'scientific method' is quite another. Indeed, in so far as a method can be identified at all its overall successful pursuit may be said to require a combination of qualities spanning both halves of the cultural gender spectrum. Consideration of these factors has accordingly led Helen Weinreich-Haste to argue that 'science is masquerading under a stereotype of masculinity' and that while male scientists, in her opinion, do get to the top of their professions by the exercise of their aggressive, masculine personalities, their creativity comes from supposedly non-masculine ways of thinking including intuition, speculation and commitment. Weinreich-Haste's conclusion is that 'knowledge needs *desexing*' and that this would entail not a change in the nature of knowledge but merely a greater awareness of what knowledge in reality is and what the processes of science actually are.[18]

There is a kind of paradox here. If scientific method were at all times a matter of inexorably following the dictates of logic and experimental evidence and nothing else, then there would be no possibility of such 'extra-scientific' factors as social or gender considerations influencing the direction of scientific advance or the content of scientific knowledge. But precisely because scientific theories are generally underdetermined by experimental evidence, and even more so 'scientific' images of nature, 'extra-empirical' factors are nearly always relevant, some of which may turn out to be the very same cultural influences that until recently led male scientists to wish to keep women out of their scientific male preserve. Particularly in biology, psychology and medicine the influence of gender factors within the domain of both knowledge and practice has been very marked and has now been much discussed. My aim here will be to examine very generally the influence of gender factors first on scientific images of nature and then on what is a frequently stated objective of scientific inquiry, the conquest of nature.

Male Science and the Image of Female Nature

One of the most striking aspects of modern science, as exemplified in the writings of many of its male practitioners, is the extent to which scientific enquiry is portrayed metaphorically as an examination of female nature by male scientists. Indeed, the historian of science, Carolyn Merchant, has suggested that one of the most powerful images in science is the 'identification of nature with the female, especially a female harbouring secrets'.[19] We may, I think, usefully illuminate Merchant's suggestion by referring to two 1984 articles on physics, each written for *The Guardian* newspaper by a distinguished practitioner. In an article entitled 'What's wrong with becoming a female physicist?' Paul Davies advises that emphasis be taken away from weapons systems, technological gadgetry and industrial activities and placed more on 'girl-friendly' and gender-neutral ideas such as 'unlocking the secrets of nature'.[20] Just two months earlier, however, in an article discussing the present exciting state of his discipline Frank Close had graphically illustrated Carolyn Merchant's thesis by enthusiastically describing modern physics as continually revealing the secrets of a female nature, explaining to readers that 'She [nature] has cleverly hidden some of her secrets from view in the macroscopic world ... She made a heavy electron ... she made a strange quark ... Why she did this is a mystery. If this was not enough she did it again' and concluding that 'By probing nature at the cutting edge may we have our eyes opened to her greater glory'.[21] Now if the pursuit by men of female secrets is seen as a particularly masculine activity, then such imagery undoubtedly contributes to the masculine image of science. Clearly the use by physicists of this kind of male-female imagery in largely informal accounts of their work contrasts vividly with the image of masculine physicists unemotionally manipulating physical apparatus in disinterested pursuit of the properties of inanimate matter. Of course, in American and British culture many industrial products culturally assumed to be under male control are often referred to by the female pronoun, especially machines such as cars, ships and aircraft. Moreover, in contrast to the property of mind which culturally tends to be seen as a male possession, matter, body and nature tend to be seen as female in character. Thus the image of the male physicist unemotionally manipulating experimental apparatus is not as distant from the image of the male physicist aggressively pursuing or lovingly revealing the secrets of a female nature as might at first sight be supposed. Yet the contrast remains striking.

Images of male scientists investigating female nature have abounded in modern science from the time of Francis Bacon onwards, ranging

from quite ferocious images of putting nature on the rack and torturing her secrets from her, together with images of unveiling, piercing and particularly of penetrating the secrets of female nature, to gentle, loving images of male wooing of a wondrous, if coy, female nature. These images are usually supplemented by metaphors of the ensuing birth of either theories or physical entities, reinforced by claims to paternity status and very often followed by impassioned paternity disputes. (Bitter indeed, for example, was Frederick Soddy's resentment at Oliver Lodge's obituary attribution of paternity status to Ernest Rutherford: 'It may be that future generations will speak of Rutherford as the father of the new atomic chemistry and physics'.[22]) Sexual imagery that is loving and gentle is suggestive of a tender love relationship as in Einstein's description of Faraday as a man of science 'who loved mysterious nature as a lover loves his distant beloved'.[23] Sexual imagery that is harshly aggressive is suggestive of rape as when the famous American astrophysicist G.E. Hale who confided to an unpublished manuscript that nature 'has hidden her secrets in an almost impregnable stronghold' wrote to congratulate Rutherford on the 'overpowering rush' of the great physicist's advance with the result that 'nature has retreated from trench to trench, and from height to height, until she is now capitulating in her inmost citadel'.[24] Gentle or aggressive, such frequent sexual imagery — particularly the frequent imagery of penetration — vividly conveys the impression of scientific enquiry as a competitive male wooing or pursuit of female nature. It is therefore not surprising if scientific enquiry comes to some extent to be seen both within and without the scientific community as a masculine competition between male scientists for the coveted status of first penetrator of female nature's secrets, the deeper the secret penetrated the greater the scientific stature of the successful researcher. Thus in a lecture delivered in 1950 A.S. Russell declared that 'the more fundamental the science the greater is the need of the big advances which only great men can make', that where great men do not exist 'the darkness remains permanently unpierced', and that 'by probing the atom to its very depth' Rutherford had illustrated 'the paramount importance of the great man in science'. More briefly but in similar eulogizing manner Max Born would refer to Rutherford in 1961 as 'the great physicist, Lord Rutherford, the father of contemporary research'.[25] Hence also arises, one might argue, a great part of the prestige of high-energy physicists since these are the men of science who with the aid of powerful accelerators are supposedly penetrating deepest into those secrets of nature which, according to the popular reductionist interpretation of nature, underlie and explain all nature's other secrets. In this connec-

tion we may note that the philosopher of science Nicholas Rescher has argued, in striking imagery, that although 'science need never encounter an absolute check in its attempt to penetrate more deeply into the secrets of nature', science can stay ahead in its 'technology-intensive arms race against nature' only by the continual creation of 'ever more potent instrumentalities of intervention'.[26]

Now apart from how adolescent school boys might react to such imagery, one is certainly entitled to question the appeal of such imagery either to girls debating whether to study physics at school or to women already practising physics. Of course, it may be that sexual imagery is not common or is even unknown in school textbooks and to this extent presents no problems (Frank Close in his text for young people *The Cosmic Onion* does not once refer to nature as 'she' and closes his book by using the metaphor of unlocking the secrets of nature, exactly the metaphor suggested by Paul Davies). Furthermore, it might be argued that even when sexual imagery occurs it is but a relatively harmless, indeed humourous, example of male sexual exuberance and can be easily written out of science in general and physics in particular. For instance, when the famous high-energy physicist and gifted expositor of physics Richard Feynman declared in one of his popular television presentations that 'nature's there and she's going to come out the way she is' this sentence was edited in *The Listener's* published version to read 'nature is going to come out the way it is'. Imagery and metaphor, it might be argued, present no problems — certainly no problems that are not removable by a trivial change of wording with everything else remaining exactly the same.[27]

Yet it is conceivable that a widespread use of (non-loving) sexual imagery, *particularly aggressive sexual imagery*, is symptomatic of underlying and possibly serious problems that will not conveniently disappear together with a determination among scientists to eliminate the use of sexual imagery from their rhetoric, lectures, popular articles and books. For not only have feminists compellingly demonstrated that Western culture has consistently been misogynist and sometimes virulently so but they continue to make clear that it also *remains* profoundly misogynist.[28] Moreover, where institutional factors and sexual relations tend to promote misogyny in men and women — by which I mean fear and hatred of perceived dangerous female qualities — they may also promote, no doubt largely at an unconscious level, misogyny in some scientists, the presence of which may at least in part be an important determinant of the way these practitioners of science come to perceive and interact with the natural world. If, for example, as Dorothy Dinnerstein has argued, both men and to a lesser extent women

experience as a result of female-dominated parenting not only love for the mother but also anger against what is perceived as powerful, uncontrolled and female, there may exist a widespread tendency shared by (some) male scientists and even female scientists to displace against 'female' nature whatever anger and rage they feel. Thus, building on the work of Dinnerstein, the political scientist Isaac Balbus has written:

> It follows that nature necessarily becomes a repository for our unconscious attitudes toward our mother. The intense ambivalence toward the mother that is the inevitable corollary of the dialectic of identification-separation-individuation will be projected onto nature: 'she' is both the mother that we love and on whom we wish to remain dependent and the mother that we hate because this wish cannot be fulfilled. Thus our love-hate relationship with our mother becomes a love-hate relationship with nature; nature will be symbolized both as the loving woman to whom we owe our life and as the dreaded, hated woman who must be dominated or even destroyed.[29]

Theoretically there exist several other equally problematic possibilities which I will mention here only very briefly. If, for example, men are generally envious of the female capacity to give birth (as has been argued by some psychologists and recently very cogently by the philosopher Eva Kittay[30]), then just as Aristotle over two thousand years ago basically wished to ascribe all creative power in sexual reproduction to male semen and none to the 'matter' provided by the female so equally today there may exist an unconscious motivation on the part of male scientists to deny any immanent creative capacity in 'female' nature and to argue instead that true creativity is rather a manifestation of the interaction between active male scientists and passive female nature. Thus the molecular biologist and Nobel Laureate Jacques Monod approvingly asserts that 'immanence is foreign to modern science'.[31] In a critique of such an attitude the physical scientist Kenneth Denbigh confirms that 'deeply ingrained in science is a view of the natural order as being passive and inert and having no initiating powers of its own' but he states and argues that such a 'notion of an inert and passive universe' has been 'read into' science as a result of the influence of various presuppositions.[32] The suggestion I make here is that such presuppositions are very likely to contain a non-trivial gender component. Another and related possibility is that if many men in patriarchal society, including many male scientists, tend to be fearful of female sexuality (as has been widely argued and discussed by historians and psychologists[33]), then scientists may not be immune, for example,

either to a largely unconscious need to view 'female' nature as inherently and unthreateningly passive or to a need to achieve total male power over 'dangerous female' nature as a way of demonstrating male virility not only to each other but also to the wider male and female publics. If these suggestions are in any way valid, then the use by scientists of male-female metaphors, particularly aggressive sexual ones, may indicate the existence of profound cultural problems and the maleness of science may be far from irrelevant in determining the general character of scientific attitudes towards the natural world. These considerations bring me to what is a very important aspect of the masculine image of science, namely the oft-stated aim of the scientific domination of nature.

The Domination of Nature

While it cannot be overstressed that modern science is not a monolithic activity and that many different sensibilities and objectives have informed and continue to inform the practice of modern science, nevertheless it also needs to be recognized that *one* of modern science's predominant features has been the goal of conquest of nature. Since conquest is culturally associated with masculinity, the fact that many prominent scientists have frequently and publicly proclaimed the objective of ever-developing conquest of nature has necessarily strongly reinforced the masculine image of science. True, many scientists have also publicly and frequently deplored what they see as a pervasive cultural image of the mad scientist recklessly intent on the conquest of nature quite unrestrained by ethical considerations — an image powerfully exemplified in Western culture by Mary Shelley's novel *Frankenstein or The Modern Prometheus*. However, despite such no doubt deeply felt and sincere protestations, the uncomfortable fact remains that many well-known scientists and spokesmen for science have often and very explicitly used a rhetoric and have proclaimed objectives for science that suggest a collective obsession with the goal of conquest — an obsession characterized by a kind of masculinity that seems to admit of no relationship with nature other than that of disconnectedness followed by total domination and subjugation.

Consider as a first example the book *Out of the Night* by the Nobel prize-winning American geneticist, H.J. Muller, which he published in 1935 at the age of 45 after contemplating the finished version for some ten years. This book, then, is not the hastily published effort of an

immature if brilliant man of science. In it Muller tells readers that 'we must try to probe further and further into the constitution and ways of working of nature as we find her', that 'there lie in the hidden recesses of the atom founts of energy that are inconceivably great', that 'nature in general must be reconstructed by us for ourselves on an ever grander scale', and that 'the mind of man must more and more become the master, not only of the outer material world, and so too of his social world, but also of the genetic thread of life within him'. He asserts that while life in its beginning was the helpless creature of its environment, it is currently in the form of man 'shaking, shaping and grinding' the immediate environment to suit its own requirements, and that in the long third phase after the mind of man has mastered its genetic basis, human life will 'shape itself into an increasingly sublime creation — a being beside which the mythical divinity of the past will seem more and more ridiculous, and which, setting its own marvellous inner powers against the brute Goliath of the suns and planets, challenges them to contest'.[34] As I have already stated, such intoxicating rhetoric scarcely represents a rush of blood to the head of one immature, if very gifted, scientist. Examples are legion. In 1965 the American physical chemist and Nobel Laureate, Willard F. Libby, wrote an article entitled 'Man's place in the physical universe' in which he announced that 'man's place in the physical universe is to be its master . . . to be its king through the power he alone possesses — the Principle of Intelligence'.[35] In similar vein, the much decorated Soviet physicist, L.A. Artsimovich, regretted in 1970 that after 'the sparkling, but also sad, success in the creation of atomic and hydrogen weapons', the seeming 'technological omnipotence of physical thinking' was being challenged by the persistently intractable problem of controlled fusion power. 'Physicists', he stated, 'simply could not remain indifferent to the fact.'[36] In 1979 the physicist Sir John Hill in his then capacity as Chairman of the UK Atomic Energy Authority dismissed critics of the nuclear power programme with the following ringing rhetoric. 'We shall be judged', he assured a joint meeting of the Institution of Nuclear Engineers and the British Nuclear Engineering Society, 'upon the facts and upon our achievements and not upon the plaintive cries of the faint-hearted who have lost the courage and ambitions of our forefathers, which made mankind the master of the earth.'[37]

This kind of rhetoric suggests that the scientific-industrial appropriation of nature characteristic of Western society since the 18th and 19th centuries, and now becoming increasingly characteristic of the rest of the world, is not only or merely a consequence of the establishment of capitalist relations of production during the period of early modern

Europe. It rather suggests that penetration into 'the hidden recesses of the atom' in the pursuit of, for example, fission and fusion power has never been solely motivated by the threat of energy shortages and of exacerbated international competition. It has also been a manifestation of that spirit so powerfully illustrated by Francis Bacon's call early in the seventeenth century to inaugurate 'the truly masculine birth of time' and thus bring about the achievement of total human power over the universe — a call echoed by René Descartes in his expressed desire for mankind to become 'masters and possessors of nature'.[38] Particularly in the case of Bacon the call was replete with aggressive metaphors of penetration into female nature. Whatever the underlying reasons, however, for the longevity of this Baconian pursuit of the total domination of nature, I think it fair to surmise that such a masculine goal of ever-increasing domination is now becoming widely seen as very much a source of ecological problems and perhaps of future ecological disaster.

With these considerations in mind, the question as to why so few girls are seemingly prepared to study physics at school might be more usefully approached in another way. Why, it might be asked, are so many boys prepared to study a subject so apparently remote from concern with living beings, a subject that prides itself on the necessity of 'hard', exact, rigorous mathematical thinking and a discipline which at best does not sufficiently dissociate itself from aggressive scientific and industrial domination of the natural world? There exist, of course, admirable, non gender-based reasons. A boy or girl would have to be very deprived educationally not to have at least a faint interest in the fascinating picture of nature which physicists such as Frank Close and Paul Davies are attempting to describe both to schoolchildren and the lay public. The gentle, humorous (if also often sad) face of Einstein — culture hero of modern physics — has, I am sure, seduced many a schoolchild.[39] There is the knowledge that physics works, and that in principle the world can be, and to some extent has been, made a better place by the caring application of discoveries in physics. Adolescent boys may also have the hope and expectation that qualifications in physics will help provide secure and humanly useful employment. But there also surely exists the attraction of the masculine aura of physics: action in a world largely 'uncomplicated by woman', the supposedly hard, rigorous method, the aggressive attitude to nature, the strong connection with industry, above all, physics' profound association with the military represented most dramatically by the creation of weapons of mass destruction together with their means of delivery.[40]

Brian Easlea

Physics, the Military and the Nuclear Arms Race

In 1980 the *American Journal of Physics* published a paper entitled 'Physics and modern warfare: The awkward silence' in which the physicist author, E.L. Woollett, claimed that some 55 per cent of all those American physicists and astronomers engaged in research and development activities work on projects of direct military value.[1] World wide it has been estimated that nearly half a million scientists work on military research and development, the majority of them in the physical sciences. To the extent that military preparation for war and the creation of weapons systems are culturally seen as strongly masculine activities (and they are certainly male-dominated ones), then the visible and substantial participation of physicists in military research and development undoubtedly greatly contributes to the already strongly masculine image of physics in general. Indeed, we might expect that the intersection of two activities each independently bearing a strongly masculine image would project the most starkly powerful image of masculinity conceivable.

Particularly interesting, I think, from this perpective is the recently published book by the high-energy physicist Freeman Dyson in which the author states that his principal objective is to facilitate communication between what he describes as the male-dominated world of the 'warriors' and the female-dominated world of the 'victims'. As a physicist himself Dyson writes that not only must he regretfully acknowledge that the professional ambitions of scientists have powerfully reinforced the nuclear arms race but because he is frequently consulted by military personnel in both Washington and California he is in an excellent position to affirm that 'the world of the warriors' is indeed overwhelmingly male-dominated and, moreover, that all who belong to this world — whether Pentagon officials, physicists, political scientists, whoever — very assiduously strive to cultivate a common style; they always try, Dyson explains, to be 'deliberately cool, attempting to exclude overt emotion and rhetoric from their discussions, emphasizing technical accuracy and objectivity, concentrating attention on questions of detail which can be reduced to quantitative calculation'. Such a style, Dyson observes, has virtually nothing in common with the style of the warriors' victims which he encounters, he states, when he attends meetings of the local citizens' peace movement in Princeton and which is exemplified in his opinion by the style of his friend and prominent anti-nuclear campaigner, Helen Caldicott. It is, Dyson stresses, a matter of considerable concern to him that, despite the fact that Caldicott is a qualified physician, the warriors apparently find it

easy to ignore her arguments on the grounds that both her style and the substance of her arguments violate the taboos of their profession. 'Her style is personal', Dyson informs,

> rather than objective. The substance of her argument is anecdotal rather than analytical. She is careless about technical details. She does not think naturally in quantitative terms. The qualities that make Helen convincing to an audience of concerned citizens in Princeton, her sincerity and seriousness and down-to-earth goodness, are outweighed in the world of the warriors by her weakness in arithmetic.[42]

The male warriors profess to practise scientific method, in their eyes Helen Caldicott does not.

After Dyson's expression of concern at such a lack of rapport between the male warriors and a principal activist in the 'peace party', it is interesting indeed to read Caldicott's own recently published appraisal of the masculine world of the warriors. For Caldicott not only denounces what she sees as the cool, calm, rational, fearless façade of the warriors — men who, she suspects, suffer from what she calls 'missile envy' — but she raises issues that perhaps many of us feel more comfortable in ignoring or quickly dismissing than in seriously considering. In speaking of the rage that she believes lies behind the warriors' unemotional façade, she speculates about its possible causes, wondering why some men apparently enjoy killing, asking if this is connected with unresolved resentment at not being able to give birth (which she describes as 'the ultimate act of creativity'); she also discusses what she sees as a dynamic of overt sexuality operating in the nuclear arms race and asks why boys and men, including 'old men', seemingly feel compelled to continually attempt to affirm their masculinity to each other.[43] Behind the apparently cool, calm, male world of the intersection of physics and military planning, Caldicott suspects the underlying existence of compulsive, motivating forces of perceived sexual inadequacy and insecure masculinity. I therefore suspect it is not so much Caldicott's putative weakness in arithmetic which makes the warriors unable to take her arguments seriously (if this is indeed the case) but rather because the questions raised and discussed by Caldicott come too close to home to be allowed serious debate. They have preferably to be ignored or ridiculed.

Caldicott, of course, is one of many female scientists and academics who have suggested that a gender and sexual dimension underlies the intersection of modern physics and military planning (as it also underlies science in general). Thus in an important book *The Gestalts of War* the

historian of military affairs, Sue Mansfield, has written at length on what she sees as the scientific style of the nuclear warriors, their quantitative methodology and technical experimentation — the style which in her opinion has led to the creation of atomic and thermonuclear weapons and manifestly informs current strategic thought. Drawing substantially on Carolyn Merchant's gender-based analysis of the seventeenth-century scientific revolution, Mansfield argues that the masculine scientific mentality with its commitment to 'objectivity' and the quantitative approach as a guarantee of truth, together with, she believes, its relegation of emotion to a peripheral and unconscious existence, has 'carried from its beginnings in the seventeenth century the burden of an essential hostility to the body, the feminine, and the natural environment'. That essential hostility, Mansfield believes, is now coming to a climax in the increasing intensity of the nuclear arms race with its ever present threat of nuclear holocaust. Should the latter happen then, together with unprecedented devastation of the natural world, there would occur (if survivors there be) the undisputed restoration of male power and authority over women. For since women generally lack hand weapons and training in their use, Mansfield argues that they would have no option in what would be a traumatically harsh post-holocaust environment but to seek for themselves and their children the protection of weapon-bearing and therefore more powerful men. Although Mansfield states that the associated goals of destruction of nature and reenslavement of women are by no means conscious objectives of our nuclear stance, she points out that 'the language of our bodies, our postures, and our acts is a critical clue to our unexamined motives and desires'.[44]

If this kind of gender-based analysis of science and its military connections has any degree of validity, then gender not only matters, it matters very much indeed. I have argued such a thesis in my own gender-based analysis of the nuclear arms race, *Fathering the Unthinkable*, where I give many examples of the aggressive sexual and birth imagery used by military scientists and strategists.[45] To that argument I would add the observation that this century began with a totally unnecessary arms race which helped lead to the First World War and is now ending with a totally unnecessary, and insanely dangerous, arms race. Interestingly, the psychologist and philosopher, William James, concluded in 1910 that gender was a central factor in explaining the existence of the arms race then being pursued by the European powers. Profoundly perplexed by the total irrationality of this arms race, since in his opinion there existed no possible conflict of interests that in any way could justify the risk of a disastrous war between Europe's major

industrial powers, the pacifistic James came to identify two fears which he believed predominated in the world of the warriors. Without war preparedness and the everpresent possibility of war, then, believed James, the military-minded feared the disappearance of the prized 'masculine' qualities of fortitude, courage and hardihood and, as a consequence of such catastrophic emasculation of men, the coming into being of an aesthetically dull, unexciting, insipid world. The warriors were indeed motivated by fear, thought James, but it was not fear of the visible manly enemy. On the contrary, it was fear of, as James put it, 'emancipation from the fear regime', fear of 'feminism unabashed', fear of a secure and peaceful world in which feminine values would predominate. In sympathy with the desire of the warriors to preserve the existence and centrality of masculine values — although in opposition to their method — James proposed what he believed would be an effective 'moral equivalent of war', namely conscription of young men to participate in perpetual all-out scientific-industrial assault on mankind's eternal enemy, the natural world. An obligatory two-year assault on nature would knock the childishness out of young men, James believed, turning them into *masculine* men, all the more appreciated by women as better teachers, husbands and fathers to their children.[46]

The idea of a moral equivalent of war did not originate with William James. As early as the seventeeth century Francis Bacon called on men to stop making war on each other and instead to inaugurate a united scientific assault on 'female' nature.[47] However, the male scientific war on nature — if this is what it has been — has not replaced male preparation for war but, on the contrary, has fed into it, leading to an unholy alliance between physicists and the military which now threatens even humanity's survival. I therefore conclude that if William James, Helen Caldicott, Carolyn Merchant and Sue Mansfield are only partly right in their respective analyses, then gender is a crucially important dimension in explaining what is happening in the super-masculine intersection of the worlds of physics and the military. The principal difference between James's prescription based on his analysis of the arms race of his day and that of contemporary feminists is, as I see it, that whereas James (with his brother Henry) apparently shared the warriors' fear of 'feminism unabashed' and sought an alternative way of preventing the dreaded emasculation of men than the way of war and preparation for war, a predominant feminist view stresses that while such a male fear does indeed lie at or near the heart of the current malaise, attempts to find alternative outlets for misogynistic masculinity will either be unavailing or will make an already bad situation worse, and that what needs to be done is rather to understand the nature of the

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male (and often female) fear of 'feminism unabashed', to identify its social-institutional-gender roots, and to make whatever changes are necessary, no matter how initially painful for most men and many women.[48]

Towards the 'Demasculinization' of Science and Physics

Gender matters very much, I believe, not only because it is profoundly unjust that institutional and other barriers still prevent women's full participation in the practice of science but also because of the strong possibility that the existence of such barriers may have much to do with the irrational state our world is in. However, there also exists the obvious possibility that certain of these barriers may be removable without thereby effecting the demasculinization of science and physics. Indeed, it may even be hoped in some quarters that the entry of more women into the physics profession will serve to strengthen its masculine practices. In February 1985 the Prime Minister told a joint session of Congress that she hoped British scientists would be able to assist their American counterparts in research connected with President Reagan's 'strategic defence initiative'. Perhaps it has recently become important to encourage girls to embark on the prolonged study of physics because in part it is believed that female physicists will tend to work in the more caring domains of physics — in teaching and non-military applications — thus freeing more of their male colleagues to work on weapons systems and in particular in the 'Star Wars' and associated military projects. Very understandably, in response to Paul Davies's *Guardian* plea of September 1984 for more girls to study physics at school, a woman teacher, Hazel Grice, asked in a letter to *The Guardian* whether it is irrational for girls to reject a subject which appears to them to offer as the apex of its achievement a weapon of mass annihilation, arguing that in her opinion 'physics will only lose its macho image when it is seen to employ its resources more usefully'.[49]

Certainly, demasculinization would entail transformation of physics into an activity undertaken by both men and women. Demasculinization, as I understand it, would also entail and bring about not only an understanding of the central importance of concern on the part of physicists for the social consequences of their work but also a sustained attempt by physicists to understand the origins and sustaining forces of male violence, especially in so far as such violence manifests itself in the practice and application of physics. A demasculinized physics would, I suggest, have many welcome features: it would no

longer be 'arrogant' or remote from concern with living beings; its method would make full use of all human qualities from intuitive capacity to the most highly developed mathematical skills; sexual imagery, if present, would generally be gentle if sometimes passionate, certainly not violent; there would exist no goal of ever-developing conquest of nature but rather the goal of respectful appropriation for human use; and there would exist meaningful institutional opposition towards the application of physics for military uses (with a possible exception made only for *genuinely* defensive military systems). Opinions differ as to how such demasculinization — or 'humanization' — might be effected. The physicist E.L. Woollett who observed that 'the physics enterprise has become a (largely) silent partner in the evolution and acceleration of the nuclear arms race' depressingly concluded that 'a member of the physics enterprise can minimize his possible contribution to military needs by either not teaching or by teaching poorly, and by either not doing research or by doing research unrelated to winning advances in basic or applied knowledge'.[50] This advice appears to be a circumlocutory way of stating that physicists ought all but stop practising physics. While the problem of the nuclear arms race is obviously a much wider one than the masculinity of physics and involves among other things the general problem of patriarchy and, I would add, the problem of capitalist social relations of production, nevertheless it surely remains the case that at the very least physicists in higher education need to undertake a serious review and substantial modification of the content of the typical physics undergraduate degree. Indeed, I fail to see how it can be seriously disputed that a significant proportion of the student physicist's time needs to be spent studying the philosophical, historical and social implications of physics with particular attention paid to the social responsibilities of physicists in the light of both their continuing contributions to the evolution and acceleration of the arms race and the general impact of advances in 'pure' and 'applied' physics on the world economy. If the viewpoint of this article is in any way correct, then such philosophical, historical and social study needs to include a substantial discussion of the gender content of physics in particular and of science in general.

How, then, might the sensibility of a 'humanized' physics and science be described? Nicholas Maxwell has argued in his book *From Knowledge to Wisdom* that a demasculinized or, as he puts it, a rational science would automatically entail that intellectual priority be given in all science courses to a consideration of human problems. He also passionately argues that 'the intellectual integrity and value of physics itself is intimately associated with its success in expressing and promot-

ing an attitude of love for nature' and he declares his hope that physicists will rejoin Kepler, Faraday, Einstein and others in once again becoming lovers of the universe.[51] (From personal experience I know I should advise members of the 'hard left' that they do not need to hurl invective at Maxwell since love for nature does not exclude its respectful appropriation for human benefit or, where necessary, its 'taming'.) Would such demasculinization imply desexualization? Since nature is typically described by scientists as female there seems to follow the implication that scientists might be well advised to desexualize their language — even gently loving language — in order to make the practice of science appear a less masculine activity. However, Cecilia Payne-Gaposchkin's autobiography not only suggests that desexualization is unnecessary but indicates that the intellectual integrity of physics as defined by Maxwell still exists, even flourishes. However, it is no doubt significant that it is a woman, not a man, who writes of her life in physics in a language that must surely warm Maxwell's heart.[52]

For the word 'love' is everpresent in the language of Cecilia Payne-Gaposchkin and the metaphors she uses to describe her life and work in physics are never aggressive ones. Moreover, her imagery is often directly sexual. She refers to her chosen discipline as 'my beloved physics', to research as 'another kind of love', and her special area of research — stellar spectra — is referred to in various places as 'my early love', 'my first loves' and 'my beloved spectra'. The practice of physics, she recalls, gave her at peak times 'pure delight', 'intense delight' and 'even greater joy' and twice she uses the word 'ecstasy' to describe her joy in discovery.[53] She describes how early in her life she was greatly influenced by the works of the Swedish mystic, Emmanuel Swedenborg, so much so that, she relates, she held throughout her life a 'mystical view of science', agreeing metaphorically with Swedenborg that 'All nature is masculine, the earth is the Mother'.[54] She also relates how when visiting the British Museum in her late teens she attempted to sketch the Demeter of Cnidos as this Greek goddess of the Earth appeared to her as 'the most beautiful creature' she had ever looked on, her youthful sonnet to Demeter beginning: 'In thy sad face the universe I see./Mother and Bride of Nature!', and she writes that fate had perhaps allowed her to be 'the only living soul that has placed a passionate kiss on the lips of Demeter'. It was a picture of Demeter that she chose to hang permanently over her work desk and which provided her with inspiration throughout her scientific life.[55] In the closing lines of her autobiographical sketch Payne-Gaposchkin writes how she believes the primal quality of nature to be its 'consistency' and the aim of true research to be to reveal this consistency in all its majesty and

grandeur. Writing of nature as 'female' Payne-Gaposchkin concludes her text: 'Nature has always had a trick of surprising us, and she will continue to surprise us. But she has never let us down yet. We can go forward with confidence

> Knowing that Nature never did betray
> The heart that loved her.'

These moving lines are followed by her poem describing as a female (heterosexual) research scientist her relationship to the universe — a universe of galaxies and stars which now becomes 'male':

> O Universe, O Lover
> I gave myself to thee
> Not for gold
> Not for glory
> But for love.
> Our children are immortal,
> I am the Mother.[38]

(How good to see a woman claiming to be the mother of research children!) Payne-Gaposchkin's autobiography makes clear in my opinion that loving sexual imagery is not out of place in describing scientific research and perhaps accurately reflects a central and even desirable motivation in the lives of some scientists, male and female. A truly human science is, after all, surely motivated by love and this love would necessarily be apparent both in scientists' concern for human welfare and in their love of nature to which a 'demasculinized' scientific research would so effectively contribute.[37] To state the matter at its briefest, the humanization of science would entail turning the present armoury that science has largely become into an open institution that takes as its central concern and with great humility the care and welfare of the planet Earth, not only human beings — all human beings — but as far as possible the vast multiplicity of living beings with which human beings share this planet, indeed the care and welfare of the biosphere in its totality. Perhaps this is a naively utopian hope. If it is, it seems to me that the world's future looks bleak indeed.

Acknowledgements

I am very grateful to Judith Clark and Andrew Graves for helpful comments on an early draft of this paper and to David Bailin for loaning me *The Cosmic Code* and *Surely You're Joking, Mr Feynman!*.

Notes

1 These data are taken from *Girls and Physics: A Report by the Joint Physics Education Committee of the Royal Society and the Institute of Physics* (1982), p. 8 and HORNIG, L.S. (1984) 'Women in science and engineering: Why so few?', *Technology Review*, November/December, pp. 33 and 41.

2 *Girls and Physics*, p. 8. The Committee members state their indebtedness to KELLY, A. (Ed.), (1981) *The Missing Half*, Manchester, Manchester University Press.

3 For example, CORINNE HUTT (1972) writes in *Males and Females*, (London, Penguin, p. 132):

> The male is physically stronger but less resilient, he is more independent, adventurous and aggressive, he is more ambitious and competitive, he has greater spatial, numerical and mechanical ability, he is more likely to construe the world in terms of objects, ideas and theories. The female at the outset possesses those sensory capacities which facilitate interpersonal communion; physically and psychologically she matures more rapidly, her verbal skills are precocious and proficient, she is more nurturant, affiliative, more consistent, and is likely to construe the world in personal, moral and aesthetic terms.

See also SAYERS, J. (1978) 'On the description of psychological sex differences', in HARTNETT, O., BODEN, G. and FULLER, M. (Eds.), *Sex-Role Stereotyping*, London, Tavistock.

4 Thus nearly four centuries ago Francis Bacon could write admiringly of Queen Elizabeth who 'lived solitary and unmarried and yet her government so masculine, as it has greater impression and operation upon the states abroad than it any ways received from thence', 'Of the Advancement of Learning' (1605) in (1951) *The Advancement of Learning and New Atlantis*, Oxford, Oxford University Press, pp. 89–90.

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16 The terms 'convergers' and 'divergers' come from HUDSON, L. (1967) *Contrary Imaginations: A Psychological Study of the English Schoolboy*, London, Penguin, chapter 3.

17 PAGELS, H. (1982) *op. cit.*, p. 339.

18 WEINREICH-HASTE, H. 'What sex is science?', in HARTNETT, O. *et al.* (Eds.), *op. cit.*, p. 179.

19 MERCHANT, C. (1982) '*Isis*' consciousness raised', *Isis*, 73, p. 402. See also MERCHANT, C. (1982) *The Death of Nature: Women, Ecology and the Scientific Revolution*, London, Wildwood.

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21 CLOSE, F. (1984) 'And now, at last, the quark to top them all', *The Guardian* 19 July, p. 13.

22 HOWORTH, M. (1958) *Pioneer Research on the Atom: The Life Story of Frederick Soddy* New World Publications, p. 328.

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26 RESCHER, N. (1978) *Scientific Progress: A Philosophical Essay on the Economics of Research in Natural Science*, Blackwell, pp. 206 and 256. CLOSE, F. (1983) *The Cosmic Onion: Quarks and the Nature of the Universe*, London, Heinemann.

27 FEYNMAN, R.P. (1981) 'The pleasure of finding things out', *The Listener* 26 November, p. 636. In his autobiographical sketches, *Surely You're Joking, Mr Feynman!* (Norton, 1985) FEYNMAN explains:

> I wanted very much to learn to draw, for a reason that I kept to

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> myself: I wanted to convey an emotion I have about the beauty of the world . . . It's an appreciation of the mathematical beauty of nature, of how she works inside; a realization that the phenomena we see result from the complexity of the inner workings between atoms; a feeling of how dramatic and wonderful it is. (page 261)

28 DOROTHY DINNERSTEIN writes: 'The hate, fear, loathing, contempt, and greed that men express toward women so pervade the human atmosphere that we breathe them as casually as the city child breathes smog'. See DINNERSTEIN, D. (1978) *The Rocking of the Cradle and the Ruling of the World*, Souvenir Press, p. 88, published in 1976 in the United States as *The Mermaid and the Minotaur*.

29 See DINNERSTEIN, D. (1978) *op. cit.*, chapter 6; and BALBUS, I.D. (1982) *Marxism and Domination* Princeton, Princeton University Press, p. 335.

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31 MONOD, J. (1972) *Chance and Necessity*, Collins, p. 137. He emphasizes, p. 114, that 'even today a good many distinguished minds seem unable to accept or even to understand that from a source of noise natural selection [a good masculine competitive force!] could quite unaided have drawn all the music of the biosphere'.

32 DENBIGH, K.G. (1975) *An Inventive Universe*, Hutchinson, pp. 7–10.

33 The social historian CHARLES E. ROSENBERG writes 'male anxieties in regard to female sexuality are as old as history itself and have attracted an elaborate, if dissonant, body of discussion; whatever metapsychological interpretation one places upon this phenomenon, its existence seems undeniable', in ROSENBERG, C.E. (1973) 'Sexuality, class and role in nineteenth century America', *American Quarterly*, 25, p. 147. See also, for example, LEDERER, W. (1968) *The Fear of Women*, Harcourt, esp. p. 283; PRESCOTT, J.W. (1975) 'Body pleasure and the origins of violence', *Bulletin of the Atomic Scientists*, November, p. 19; CARLTON, E. (1980) *Sexual Anxiety: A Study of Male Impotence*, Martin Robertson; ROTH, M. (1982) 'Pornography and society: A psychiatric view', in YAFFE, M. and NELSON, E.C. (Eds.), *The Influence of Pornography on Behaviour*, Academic Press, esp. p. 15.

34 MULLER, H.J. (1936) *Out of the Night*, Gollancz, pp. 62, 74, 76 and 156–8.

35 LIBBY, W.F. (1965) 'Man's place in the physical universe', in PLATT, J. (Ed.), *New Views of the Nature of Man*, Chicago, Chicago University Press, p. 15.

36 ARTSIMOVICH, L.A. (1970) 'Controlled nuclear fusion: Energy for the distant future', *Bulletin of the Atomic Scientists*, June, p. 48. I am indebted to

JUDITH CLARK for drawing my attention to this article and to the quotation in the text.

37 HILL, SIR JOHN (1979) 'The quest for public acceptance of nuclear power', *Atom*, 273, p. 172.

38 See, for example, the discussion in my *Science and Sexual Oppression* (1981), London, Weidenfeld and Nicolson, chapter 3, especially pp. 84–5.

39 See the article by ELIZABETH JOHNSON in this volume, 'On being a scientist'.

40 The phrase 'uncomplicated by woman' comes from PRIESTLEY, J.B. (1963) *Margin Released*, The Reprint Society, p. 86, who describes how some of his male contemporaries welcomed front-line combat as 'a wholly masculine way of life uncomplicated by woman'.

41 WOOLLETT, E.L. (1980) 'Physics and modern warfare: The awkward silence', *American Journal of Physics*, 48, p. 107.

42 DYSON, F. (1984) *Weapons and Hope*, Harper and Row, pp. 4–7. In his book *Thinking about the Unthinkable* (1962), Weidenfeld, p. 35 the ex-Los Alamos physicist and nuclear strategist HERMAN KAHN writes, 'Critics frequently refer to the icy rationality of the Hudson Institute, the Rand Corporation, and other such organizations. I'm always tempted to ask in reply, "Would you prefer a warm, human error? Do you feel better with a nice emotional mistake?"'.

43 CALDICOTT, H. (1984) *Missile Envy: The Arms Race and Nuclear War*, WILLIAM MORROW, chapter 8, 'Etiology: Missile envy and other psychopathology', pp. 294, 296 and 305.

44 MANSFIELD, S. (1982) *The Gestalts of War: An Inquiry into Its Origins and Meaning as a Social Institution*, Dial Press, pp. 223 and 225.

45 EASLEA, B. (1983) *Fathering the Unthinkable: Masculinity, Scientists and the Nuclear Arms Race*, London, Pluto Press.

46 JAMES, W. (1982) 'The moral equivalent of war', in *Essays in Religion and Morality*, Cambridge, MA, Harvard University Press, pp. 162–73.

47 See *Fathering the Unthinkable*, pp. 20–1; SPEDDING, J. *et al.* (Eds.), new edn (1879–90), *The Works of Francis Bacon*, Vol. 4, p. 373.

48 Again I refer the reader to DOROTHY DINNERSTEIN's outstanding book (see footnote 28 above).

49 HAZEL GRICE, letter to *The Guardian*, 9 October 1984, p. 20.

50 WOOLLETT, E.L. (1980) *op. cit.* p. 106.

51 MANWELL, N. (1984) *From Knowledge to Wisdom: A Revolution in the Aims and Methods of Science* Oxford, Blackwell, pp. 7 and 135.

52 HARAMUNDANIS, K. (1984) *op. cit.*

53 *Ibid.*, pp. 84, 115, 146, 165, 169 and 170.

54 *Ibid.*, pp. 53 and 235.

55 *Ibid.*, pp. 235–6.

56 *Ibid.*, p. 237. Interestingly, a male astronomer, JESSE L. GREENSTEIN, writes in his Introduction to CECILIA PAYNE-GAPOSCHKIN's autobiography,

> I did not have her personal friendship with individual stars. She

> could describe fondly the eccentric behaviour of certain spectral lines in a southern supergiant. But her intuition as to what was important in astronomy was truly deep . . . Most important, [her work] showed the bravery and adventure of a mind exploring the unknown with the available scientific apparatus and a complete belief in the power of human reason and logic. (pp. 8–10)

57 Vehemently rejecting the image of putting nature on the rack and torturing the answers out of 'her', the female biologist called ANNA BRITO by JUNE GODDFIELD explained:

> I'm going to put it in a totally different way. Again I say the nearest an ordinary person gets to the essence of the scientific process is when they fall in love [and she described the moment of discovery or success as] the orgasmic moment. It is an exciting and most *intimate* moment. You can get that moment from a graph, or from numbers in a machine, or you can get it under a microscope. So that is why, whenever you ask me about science, it is always images of enthusiasm, innocence, freshness, and love that come into my mind.

GODDFIELD, J. (1982) *An Imagined World: A Story of Scientific Discovery*, London, Penguin, pp. 228–30.

9 *The Making of a Scientist?*

Jan Harding

Introduction

I have borrowed the title for my article from the book by Anne Roe (1952) but have added a question mark so that I am asking, '*Is* this how scientists are made?'

Anne Roe reported on the background and personality of eminent scientists — all of them male — who had been the subject of her personal enquiry.

My article does not report on a specific study; it is an outcome of many years work within science education crystallized through discussions within a Gender and Education Group based at the Centre for Science and Mathematics Education at Chelsea College.[1] As its name implies, this is a specialist centre committed to research and development in science education and to the training of science teachers. We were therefore professionally involved with the making of scientists and were particularly concerned about the underchievement of girls and women in science.

The tools of scientific investigation become ever more sophisticated, making research more expensive, and the fields themselves become more complex. Thus, the making of a scientist is inevitably a long and selective process with its foundations laid in crucial early choices made by individuals. Science education in schools forms an important element in this process. The questions we were asking were — how does the content and presentation of school science interact with personality and how may this interaction lead to an alienation of girls and women from science?

Post-war research in science education has focussed largely on cognitive factors such as conceptual levels, alternative frameworks and the concepts children bring to school science (Archenhold *et al.* 1980).

Few, if any, studies have addressed motivational or engagement aspects of learning and yet these, surely, must precede cognitive learning to some extent for the latter to be meaningful to the learner.

In the context of concern over a 'swing from science' a majority of studies identified characteristics or factors which differentiated between those who chose science and those who did not. Positive decisions for science were found to have been made earlier than those for arts subjects (Kelly, 1961). Those choosing the former were convergers, while those choosing the latter were divergers (Hudson, 1966) and sixth-form scientists were less person-orientated than those studying the arts (Smithers and Collings, 1984).

But in the literature there are interesting aspects of empirical studies which suggest that the choice of science and technology can be made for different reasons and that these differentiate between females and males.

Ormerod (1971) showed that the recognition that science has social implications correlates with girls' choice of it but not with boys'. When Hudson (1968) included girls in his studies, they did not fit the pattern of science choice by 'convergers' which had been established earlier for boys (Hudson, 1966). Head's (1980) work suggests that it is the less mature boy but the more mature girl who tends to choose science. In the technology area, an analysis of entries over a three-year period by 14-year-olds, to a national design prize competition, was made (Grant, 1982): boys and girls worked on similar devices but their statements of the problems they were tackling differed. The boys generally identified the problem in the device, which they set out to improve, whereas, for the girls, the problem lay in the social context and the technology merely facilitated the solution. And Smithers and Collings' girl scientists were more person-orientated than even the boys enrolled in arts courses!

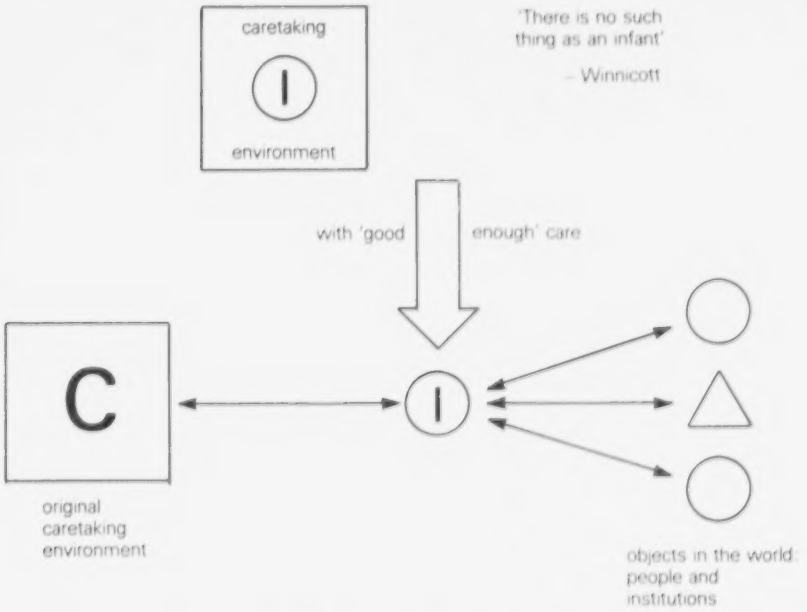
We may conclude from these, and other studies, that boys and girls are, generally, differently connected to the world through values and responses. It is the purpose of this article to explore how this may come about and to suggest that the differences may extend to what may be termed 'cognitive style'.

We have found in object relations theory a useful developmental model which seems to make sense of much of this empirical work. (Harding and Sutoris, 1984). The importance to the developing child of 'objects' and its relationship to them was first emphasized by Klein (1932). Objects are representations, created by the individual, usually of people, things and institutions (such as 'school' or 'science', etc.). The individual then relates to these created objects. Winnicott, for many years a pediatrician and for a time a pupil of Klein's, modified the

theory to account for data accumulated over many years of consultations with parents and their children.

For Winnicott (1965) the task facing the infant is to separate out from its total dependence on its primary caretaker(s) to become an autonomous adult able to relate with mature interdependence to people and institutions in the world (see figure 1). The task the caretaking environment is to provide nourishment, to present the world and to protect the developing child from too much stress. The last two require a delicate balance, which enables separation but offers adaptive care until the child is able, progressively, to take over functions for itself.

Figure 1: An Object Relations Account of Personal Development



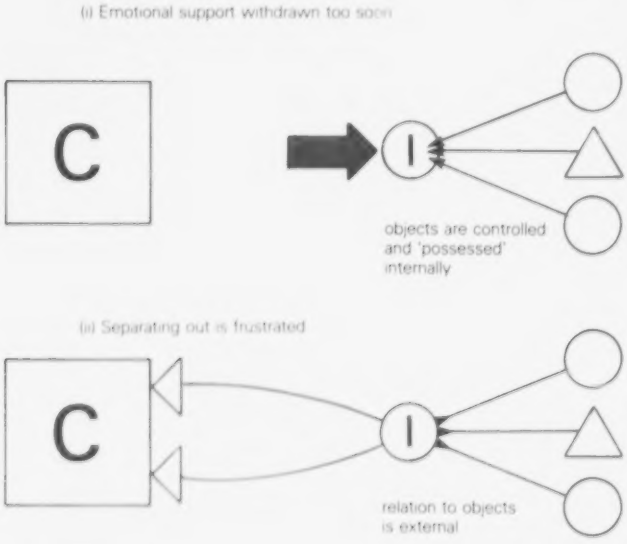
Two important early developments (among others) are 'a sense of feeling real' and 'a capacity for concern'. The first is facilitated by activity, bringing the infant up against hard physical objects in the environment. This lays the foundations for assertiveness and a sense of control. The second develops from guilt feelings in the child as it begins to appreciate that in taking from the 'provider' it may be harming the 'protector'. To work through this sense of guilt, to 'make reparation' and to achieve a 'capacity for concern', the child needs quiet times with the provider/protector.

Archer and Lloyd (1982) describe the behaviour of a mother asked

to care for an unfamiliar child aged six months. If it was dressed as a boy she activated it but another mother pacified and held it close if the same child was dressed as a girl. This suggests that girls may be deprived of experiences which facilitate control and a feeling of reality while boys lose out on opportunities to develop a capacity for concern.

Winnicott further elaborated the two chief ways in which the caretaking environment may fail the developing infant (see Figure 2). One is if adaptive care is withdrawn too soon, when a 'separation anxiety' develops. The technique which copes with this is the seeking in other objects their certain, reliable aspects, abstracting these and relating to them internally by possessing and thus controlling them. 'Taking' is a feature of such a child and emotional giving is especially difficult.

Figure 2: If things go wrong –



On the other hand the protective function of the caretaking environment may persist after the child is able and eager to take over the adaptive function for itself. Although a capacity for concern may be generated, 'merging anxiety' develops. The child experiences frustration and a hatred may develop for the caretaker(s), whose loving relationship it values. Such an ambivalence is intolerable and so the

developing young person may suppress the desire to separate out and dependency persists with a tendency to conform and 'fit in'. The development of autonomy will be constrained as will a robust sense of self.

The first condition more commonly applies to boys than to girls and the second more to girls than to boys. Head (1980) identified the personality characteristics described above in adolescent boys who chose science and he suggests that by presenting science as a system of generalizations and immutable laws, divorced from the problems of the world (as much physical science is taught in schools) we attract into it largely males of a particular personality type. Supporting evidence comes also from Anne Roe's scientists. A considerable number of these reported some kind of emotional trauma in childhood, either the loss of someone close or a period of illness which isolated them from their fellows, resulting in an adult personality characterized by emotional reticence and low person orientation. Head's review (1979) suggests this is a valid general conclusion from a number of studies.

Head's (1980) work also showed that girls are more likely to demonstrate a capacity for concern and an ability to see things from another person's perspective. That girls feel a need to help others emerged from the National Child Development Study[2] in the UK. When asked at age 16 what to them were important criteria in seeking a job 25 per cent of girls, but only 4 per cent of boys, placed 'that it should enable me to help other people' in first position. Gilligan (1982) reports a twelve year old girl saying:

> I want to be some kind of scientist or something, and I want to do things and I want to help people . . . I think that everybody should try to help somebody else in some way, and the way I'm choosing is through science. (p. 34)

Here science is chosen, not for the protection it affords from the world, but for its potential for improving the quality of life. We may therefore conclude that if girls are enabled to make of science an object which is clearly embedded in the social context and in which its potential for solving human problems is made explicit, many more of them may be motivated to work within it instead of making crucial choices against science in early or later adolescence.

Once within science the success that some will experience may lead them to a more intrinsic commitment. On the other hand, as Anne Walton's studies have suggested[3], they may at a later stage, when able to select a research field for themselves, seek it within a social or humanitarian context.

So far this article has considered values and emotional responses, but the explanatory power of the object relations model may be extended to cognitive processes. For those deprived too early of adaptive care the process of looking for certainty and suppressing ambiguity is likely to create a view of the world which is logically simple and unproblematic, many peripheral implications may readily be ignored. Knowledge will be created by the process of abstracting and controlling and will probably be compartmentalized. The contribution of such persons to discussion is likely to take the form of separate personal statements not necessarily informed by those made earlier. On the other hand for those whose separation from the caretaking environment is thwarted, external objects are valued precisely for their externality. Those nurtured in this way tend to relate externally to objects and the boundaries between self and the world are not clearly delineated. Chodorow (1978), who uses object relations theory in an account of 'the reproduction of mothering', states that 'the basic feminine sense of self is connected to the world, the basic masculine sense of self is separate'. If this is so, women may be attending to a multiplicity of signals from 'the world' all the time (it is possible to see in this an explanation for women's so-called 'intuition'). They will respond positively to knowledge presented as making sense of a multiplicity of apparently disparate experiences. In debate they will constantly be testing what they hear against what they know and assessing whether they have any contribution to make that will further the discussion. They will be less likely to interrupt others and will require longer pauses for insertion. Different cognitive styles may therefore contribute to the male domination of public discourse that Spender describes (1980).

The former, male, style closely resembles what Keller (1983) refers to as the popular mythology of the pursuit of science. She also draws on object relations theory in discussing the meaning of 'objective' and 'objectivity' in an analysis of the masculine image of science. She deplores the current trend in 'feminism' which identifies women with nature and places it in opposition to science and urges the adoption of an 'ungendered' science which more truly represents the processes involved in many of the major developments of science. In particular she cites the work of Nobel prize-winner, Barbara McClintock, for whom objectivity has a rather different meaning from that of the total isolation of self from the material studied. McClintock claims that in studying minute chromosome systems 'I wasn't outside. I was down there — I was part of the system'. It is important to have 'a feeling for the organism' and to 'let the material tell you what to do'. A similar approach emerges from Goodfield's (1981) account of the work of a

Portuguese woman scientist 'Anna Brito' and in Jane Goodall Lawick's work with chimpanzees.

It may be no accident that these different approaches have been successful within the more complex fields of the life sciences. Perhaps isolating/controlling techniques have been peculiarly successful in the physical sciences where variables are fewer and systems are more readily isolated for investigation.

Conclusion

To return to my original question '*Is* this how a scientist is made?' I am suggesting that an object relations account of personal development provides an explanation that integrates much existing empirical research.

Science is an institution in the world which is progressively presented to the child. The latter creates of science an object to which it then relates. The nature of this object and of the relationship to it will depend on the outcome of nurturing of the child, on the forms in which science is presented and how these interact.

Personality studies of practising scientists at various levels from sixth-form science specialists to Nobel Laureates suggest that a science object which is reliable and immutable which enables control (both tangibly and intellectually) and which may be pursued in a detached, emotionless way is created and used by individuals for whom nurturing has been deficient in emotional support — and these form a majority of scientists.

On the other hand a different outcome of nurturing which facilitates relatedness, a capacity of concern and avoids the need to possess and control will result in individuals who may be able to create for themselves a science which is more firmly based in the social context and which is pursued in a less dominant, separatist mode. To be able to contribute professionally to science, however, such persons must be enabled to develop autonomy and an adequate sense of self.

The kind of science created and shaped by individuals from these different groups may be substantially different and will certainly be driven by different values.

Unfortunately, as indicated earlier, the formal presentation of science in education at crucial stages of personal development and decision-making — in secondary school and in undergraduate courses — is more likely to match the first case rather than the second. As the first is typical of males and the second of females, more males are attracted

into science even where it appears that opportunities are equally open to both sexes; but the males may be of a particular personality type and use a cognitive style which limits creativity. Not only does this selective process disadvantage women but it limits the development of science and may create hazards for society.

If we wish to open up the practice of science to women and a wider range of men, we need to make changes firstly in our nurturing of children, so that boys may develop a greater sense of relatedness and less need to control and posses, and girls, while still developing a capacity for concern, may acquire greater autonomy and a clearer sense of self. Secondly, we need to change the presentation of science curricula to emphasize the relationship between science and the human condition and to encourage a range of teaching/learning approaches to accommodate differences in cognitive style.

Nancy Chodorow claims the way forward is to involve men more fully in nurturing. In which case the making of a more flexible scientist of either sex may depend on the extent to which mothering is undertaken by men.

Notes

1 Chelsea College became part of King's College, London in August 1985. The Centre for Science and Mathematics Education is now part of the Centre for Educational Studies, King's College.
2 A longitudinal study of some 11,000 individuals born in the first week of March in 1958.
3 See article by Anne Walton in this volume.

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10 *How Gender Matters, or, Why It's so Hard for Us to Count Past Two*

Evelyn Fox Keller

I often think that the juxtaposition of the terms gender and science serves as a kind of Rohrschach test — by which I mean that the responses and associations it evokes can be read as a key to deep conflicts and confusions about both gender and science that almost all of us live with. These conflicts and confusions are manifested in a number of ways — perhaps all of them variants of what we might call the one-two step (or sometimes the two-one step).

One version goes like this: in my new book, I tell an anecdote illustrating a rather typical response I get from people when I tell them that I work on gender and science. 'How interesting', they say. 'What is it that you've learned about women in science?'. The replacement of 'and' by 'in' is clear enough, and perhaps not too indicative, because we all tend to be pretty sloppy about the little words in our language, but the replacement of gender by women is both less clear, and, I think, finally more significant. But even accepting this replacement, there are still roughly three variants or stages — like stages of cognitive development. In the first stage, the reality— both social and cognitive — that is implicitly presupposed is fixed. Gender is determined by biology, and science, by nature. People (along with other animals) manifest in their behavior their inner natures as determined by the presence of an X or Y chromosome. In this framing of the world, where there are two genders, and one science, the subject of gender and science becomes fairly boring — it immediately reduces to a discussion of 'why women are unfitted for science'. Such a discussion may in fact be no longer fashionable these days, but it is nonetheless still logically compatible with the basic assumptions that are, if anything, newly fashionable — at least in some quarters (particularly sociobiology and certain kinds of brain research).

A slight increase in sophistication leads us to see these claims as referring to 'stereotypes' about gender. We can call this stage two. Now, the subject of gender and science becomes translated into 'Women

aren't really unfitted for science; they are only said to be so' — or, with yet a little more sophistication, 'Women aren't unfit for science by nature, only by nurture — i.e. they are made so'. That is to say, the world is truly unitary, divided only in appearance — either (merely) by language, or, (merely), by social convention. Our task, therefore, as enlightened critics, is to restore its natural unity. This is the two-one step — it is the move that has historically been taken by women in science, and for good political reasons. Women had observed that the division of the world into two serves them poorly — it serves to exclude them from the domain of public life, of power, and of science. The claim that we are different meant that we are less. Quite reasonably, therefore, women fighting for admission into the world of science countered with the claim, no, we are not different. But, there's a hidden kicker in this move, that only becomes evident with the question: different, or not different, from whom? (This is inverse of the joke in *Ruggles of Red Gap* when Ruggles says, 'all men are created equal' and he is asked, 'equal to what?'. Stymied for a moment, he finally responds, 'to women'.)

The problem of the hidden referent in this strategy appeared not to concern most of these early feminists— certainly not nearly as much as it has begun to worry modern feminists. We are speaking of course of the problem that inheres in the fact that the universal standard is after all not neutral — of what happens to our strategy, and our thinking about gender and science when we begin to notice that the universal man is, in fact, male. The first thing this recognition enables us to do is to begin to make sense of the failure of the promise of equity. To be included in the big 'one' means not to be equally represented, but to be unrepresented. It is to be swallowed up whole, negated in the quest for assimilation — as it were, a hole in 'one'.

A simple story may serve to illustrate. A committee recently convened by the Macy Foundation was charged with the task of determining the causes of continuing inequity of women in the biological sciences. After reviewing possible claims of ongoing discrimination, the Committee rejected these as explanations, and concluded that the problem lay elsewhere. 'Women', they felt obliged to conclude, 'are not sufficiently aggressive to successfully compete at the forefront of modern research'.

This is a point worth pausing at in order to take note of the fact that it did not occur to anyone on the Committee that there was in fact more than one possible response to this judgment, namely, 'How can we train (or remake) women to be more aggressive?'. When I tried to suggest the possibility of alternative responses to a member of the Committee, she

proved remarkably resistant, until, all of a sudden, she turned to me: 'Do you mean to say there would be a female science?'

This is the one-two step. Gender has become abruptly collapsed back into sex, reminding us that there really are two. But now, instead of, as in the first stage, two sexes and one science, the suggestion is that there are two sexes and two sciences. Men and women are once again born, but now science is made. This I might call stage three.

When it comes, this shift — from no difference, or universality, to absolute difference, or duality — comes surprisingly fast. Certainly, it came very fast in the recent history of the subject of gender and science. My own first attempts to discuss these issues (as recently as 1978) met with absolute resistance — even, or perhaps even especially, among feminists. Just a few short years later, the notion of a feminist science — by which people usually mean a feminine science — has become something of a rage. It is rather like the invertible figure ground diagrams — the ease and rapidity of the shift suggesting that universality and duality are, in some basic sense, two sides of the same coin.

(Because confusion is so easy here, let me make it absolutely clear that this is not an argument for duality — for a female science either to replace or supplement a male science. That is, I do not believe that science is written in our chromosomes — neither in the X nor the Y chromosome.)

We can see a somewhat different version of the same one-two step when we look at another tack people have taken in their thinking about gender and science — a tack which focusses not on the sociology of sex and gender but on its biology. Which is to say, where the issue of concern becomes the biology of sex (in biological terms, there is no language for distinguishing sex and gender). Note also though, that the biology of sex in turn, again tends to be translated into the biology of women.

Here, feminists — many of them the very same feminists who fought against forms of stereotypic socialization that work to exclude women from science (and other domains of power), now turned their attention to the uses of biology in perpetuating the exclusion of women — where biology is not any longer understood as biological nature, but as a scientific construction. That is to say, these critics put a wedge between science and nature rather than between sex and gender.

In short, feminist scientists began to think about the political and social contributions to sexual segregation made by their own profession, — giving rise to such critiques as *Alice Through the Microscope* (Brighton Group, 1980), *Women Look at Biology Looking at Women* (Hubbard, Henefin and Fried, 1979), *Woman's Nature* (Hubbard and

Lowe, 1983) or more recently, *Science and Gender* (Blier, 1984). In much of this work, we find a view on the subject of gender and science that might be represented by the translation of science and gender to the science of gender, and more specifically, to the biology of women.

What emerges from these extremely important and valuable analyses is the inescapable conclusion that the science of gender is not very scientific — whether we are talking about hormonal studies, brain studies, or sociobiology. Indeed, the science of gender appears to be no more scientific than the science of race has been. The claims of sex differences — like those of race differences — are more often properly seen as the starting points of these studies, rather than the conclusions. But where in the past, critiques of bias and ideology in the science of race led to a repudiation of this work — by scientists and liberals alike — as scientifically flawed, — i.e. racist science was bad science — here, a major strain of the feminist critique of the science of gender does not remain content with the equation of androcentric or misogynist science with bad science, but goes beyond the repudiation of the science of gender as failing in objectivity, to a repudiation of objectivity itself as an androcentric value. The need, it is now concluded, is not simply the upholding of more rigorous standards but a different kind of science — perhaps a 'gynocentric' science. This is an extraordinary move — for a number of reasons.

First, like the one-two step before, it takes us from a position predicated on the denial of sex differences to one which affirms sex differences, with hardly a blink. Second, it is a move which effectively undermines the very critique that led to it. That is, step two is a step which undoes step one. If objectivity is a male value, a code word for domination, and therefore not good science, then subjectivity is a female value and good science is one which affirms good values. Or, unpacking this move a little more, it goes from showing that science is not always value free, to the position that all science is inescapably value laden. Hence the equation between good science and value free science breaks down, and can be replaced by another equation: good science is science that embodies good values. If science does not mirror the oneness of nature, then it must mirror the twoness of us. But now our critique of the science of gender has in fact become redundant. What matters is not that that work is not objective, but that it embodies the values of patriarchy. (Parenthetically, we might note a step which appears to follow quite easily — namely from the twoness of us, to the infinity of us's. That is, having given up on objectivity, we might be tempted to say that there are as many sciences as the perspectives we might hold — indeed, infinitely many. While I suppose that this shift might be

characterized as counting beyond two. I think rather that too swift a move from two to infinity belies a more sophisticated numeric capacity, — that rather, infinity here is simply another name for a different kind of oneness.)

What I suggest is that the case of the transition from one to two, or even from two to infinity, is indicative of a more general problem, or paradox, latent in much of contemporary perceptions about science — not only in discussions of gender and science. Many people, including scientists themselves, seem to believe, at one and the same time, that 'of course' the practice of science is not objective, and 'of course', what distinguishes science, and accounts for its triumphs, is precisely its objectivity. The first of these beliefs owes a large debt to a pair of ideas emerging from the philosophy of science in the early sixties, and then rapidly rising to favor: One is that 'observation is theory laden', and the other, that theories are value laden. Half assimilated, these ideas coexist, more or less uncomfortably, with the continuing claim that the practice of science justifies itself by 'progressive' discovery and successful prediction.

In other words, the same kind of schizophrenia plagues our thinking about science as plagues our thinking about gender — both fixed, natural categories in one moment, and constructed, perhaps even indefinitely plastic, categories in another. Having no good way of mediating between these two sets of insights, we manage to slip readily from one to the other — back and forth between objective realism and relativism on the one hand, and between universality and duality on the other. The question is: How can we get past this impasse?

I suggest that a better understanding of the insights from both feminist theory and the social studies of science, and even more, an integration of these insights, points us in the direction of resolving these paradoxes — towards learning to count past two, and in the process towards a radically expanded meaning of what the subject of gender and science is about. Feminist theory has brought home to us that gender is neither simply the manifestation of sex, nor simply an easily dispensible artefact of culture. It is, instead, what a culture makes of sex — it is the cultural transformation of male and female infants into adult men and women. All cultures do this, but they all do it somewhat differently. Invariably, how they do it — how they organize the spectrum of human attributes around sex — has a significant impact on their structuring of the world beyond sex as well — indeed, it permeates all aspects of their existence.

Similarly science is neither a mirror of nature, nor simply a reflection of culture. It is the name we give to a set of practices and a body of

knowledge delineated by a community — constrained although certainly not contained by the exigencies of logical proof and experimental verification.

The relationship between gender and science is a pressing issue not simply because women have been historically excluded from science, but because of the deep interpenetration between our cultural construction of gender, and our naming of science. The same cultural tradition that names rational, objective, and transcendent as male, and irrational, subjective, and immanent as female, also, and simultaneously, names the scientific mind as male, and material nature as female. Beginning with Francis Bacon, and continuing into our own times, the very same sexual division of emotional and intellectual labor that frames the maturation of male and female infants into adult men and women also, and simultaneously, divides the epistemological practices and bodies of knowledge we call science from those we call not-science. Modern science is constituted around a set of exclusionary oppositions, in which that which is named feminine is excluded, and that which is excluded — be it feeling, subjectivity, or nature — is named female. Actual human beings are of course never fully bound by stereotypes, and some men and some women — and some scientists — will always go beyond them. But at the same time, stereotypes are never idle. To a remarkable degree, to learn to be a scientist is to learn the attributes of what our culture calls masculinity. It is to learn how to perform in (or on) a (conceptual) world definitively cleft in two. This core observation — of the historic naming of science as male and nature as female, and of scientific as masculine, and unscientific as feminine — causes an immediate expansion of the subject of gender and science. From the comparatively simple questions about women in science, or about the biology of women, grows a much larger set of questions about how our ideas of gender have helped shape our construction of science, and how our ideas about science have influenced our construction of gender — in short, it becomes a study of the simultaneous making of men, women and science. And it is to this study that much of my own work — as well as that of a growing number of other feminist scholars — has been devoted.

By now, we have a considerable literature that has documented an extensive interpenetration between scientific, philosophical and gender discourse. This literature has emerged in a critique of traditional notions of objectivity as deeply intertwined with traditional notions of masculinity. I would argue that in the effort, important aspects of the social, historical and psychological dynamics of this intertwining have been illuminated. But in many ways, the question that must inevitably be of

greatest interest to scientists — namely what difference does such a gendered discourse make to science — that question has only begun to be addressed. It is easy enough to say, and to show, that the language of science is riddled with patriarchal imagery, but it is far more difficult to show — or even to think about — what effect a non-patriarchal discourse would have had — or would now have (supposing i.e. that we could learn to ungender our discourse)? In short, *what does language have to do with science?* This, I suggest, is the real task that faces not only feminist critiques of science, but all of the history, philosophy and sociology of science.

The major problem that confronts us in this task derives from the fact that modern science, as we know it, has arisen once and only once in cultural history. That is, we cannot say of science what we can say of gender — namely that all cultures do it. We cannot look to other cultures, with other gender systems, and ask how their science is or was different for the simple reason that the knowledge practices of other cultures do not conform to what we call science. (The same difficulty applies to the question of more women in science.) The point to keep in mind however is that this inability reflects not so much the failure of other cultures, but precisely the social character of the process by which science gets named — even, or especially, good science. And in fact, attending to this process shows us a way out of our difficulty.

What all social studies of science see when they look closely at the process by which good science is named is a variety and range of practices, visions, and articulations of science far in excess of any ideological prescriptions. As in the case of gender stereotypes, ideological norms may be formative but they are never fully binding. In every period of scientific history, in every school of science, we can see a rich diversity of meanings and practices. In fact, it would appear that where ideology makes its force felt most crucially is in its role in the process by which some theories, methodologies, and explanations are selected as representative of good science and others are discarded. Scientific proof — be it logical or experimental — is rarely if ever enough to make this judgment. Indeed, even the criteria of proof are themselves selected in a complex social process that includes social, political, and psychological factors.

This is, in fact, the real point of the McClintock story. The success of Barbara McClintock, the 1983 Nobel Laureate in medicine and physiology, forces our acknowledgement of the existence and the value of deviance in science. As such, her example stretches our conception of science — teaching us to count past two in our division between scientific and non-scientific. Her success serves to legitimate a vision

and practice of science that contemporary standards had almost lost sight of. In short, what McClintock brings home to us is a lesson in diversity.

In turn, the particular character of her vision and practice of science teaches us to count past two in our thinking about nature, as well as in our thinking about the relation between mind and nature. McClintock offers us a vision of science that begins not so much with the search for generality, as with a primary interest in and respect for difference. For her, the important thing is the capacity to see one kernel — she is a corn geneticist — that is different, and make that difference understandable.

But what is distinctive here is that making difference understandable does not mean making it disappear. In McClintock's world view, an understanding of nature can — indeed, must — come to rest with difference. It is in fact because of the inescapability of difference, that she says, 'There's no such thing as a central dogma into which everything will fit'.

What McClintock in effect offers us is a philosophy of science in which difference — rather than division — constitutes the fundamental principle for ordering the world. Instead of aiming toward a cosmic unity of paired opposites — a unity typically excluding or subsuming one of the pair, respect for difference remains content with multiplicity as an end in itself.

Nor, in this world view, is division between subject and object posited as a prerequisite for knowledge. For McClintock, the *sine qua non* of good research is a feeling for the organism — hence the title of my book (Keller, 1983). Respect for individual difference here invites a form of engagement and understanding not representable in conventional scientific discourse. What might look like privileged insight, and is readily misdescribed as a kind of mystical experience, is in fact a result of close, intimate attention and patient observation — maintained over days, weeks and even years. Even Freud, who added so much modern credibility to the number three in his thinking about man, seemed himself only able to count to two in his thinking about subject object relations: Freud too seemed only able to think in terms either of objectivity or of what he called oceanic oneness. But McClintock's practice of science offers another possibility — it teaches us about a world in which self and other, mind and nature, survive neither in mutual alienation nor in symbiotic fusion, but in structural integrity. Her feeling for the organism need not be read either as sentimentalism or as mysticism: it is a mode of access — honored by time and human experience if not by prevailing conceptions of science — to the reliable

knowledge of the world around us that all scientists seek.

Finally, McClintock also teaches us to count past two in our thinking about gender. Many people have read this story as a story about a feminist science — by which they usually mean a feminine science. And it is easy enough to see why. Virtually all of the aspects of McClintock's science that seem so distinctive — the value she places on feeling, intimacy, connection and relatedness — all seem to confirm our most familiar stereotypes of women. She is — on this I would agree — bringing to science precisely those attributes that have traditionally been devalued as feminine.

Indeed, some people might say that the celebration of these traits is indicative not so much of the ability to count past two, but of an inability to count to two (if one is inclined to be negative) or (in a more positive vein) a special capacity to count between one and two. That is, women, it is often thought, tend to live in a domain between one and two, where self and other are never — again, the negative account would have it, fully differentiated, while the positive view would put it, cast in opposition. Many kinds of accounts of why this might be so are offered. One roots it in the biology of pregnancy — a kind of paradigmatic experience of a nether world between one and two. Other accounts would root this capacity, or, inability, in the dynamics of the early mother-daughter relationship, (notably, as experienced by the daughter) — a relationship which fosters identification if not more than, at least along with, separation. And still other accounts would root it in the emphasis on relationship and attachment demanded of parenting, a task usually performed by mothers. In the feminist version of these accounts, the space between one and two is celebrated, while in the traditional version, it is denigrated. That is, recent feminist writings have sought to restore a domain of values lost by a numeric scheme limited to the numbers one and two. But while I support such an effort, I also have a problem with this view as stated. Perhaps one move that would help to reconcile it with the position I am arguing here — would be to suggest a structural homology between the space between one and two on the one hand, and between two and infinity on the other, and I do make this suggestion. The capacity to count between one and two may in fact foster the capacity to count beyond two.

But that move will not do all the work of reconciliation that is required. Even though I do not want to repudiate these insights — and have in fact argued for some of them in my writing — I do want to register some reservations about these accounts as representations of women in general, and about the implication that only men get stuck in the one-step. Indeed, the examples I began with are illustrations of the

difficulty in counting past two among feminists themselves. Furthermore, and more specifically germane, I need to point out that none of these accounts is relevant to McClintock herself. McClintock was never pregnant, never parented, and, although she was a daughter, she had a rather anomalous relation to her mother — certainly not one that conforms to stereotypic accounts. Furthermore, her entire life was devoted to a repudiation of all feminine stereotypes, — and this repudiation may even have been necessary to her survival as a scientist. What relevance, then, if any, can we say that McClintock's gender has to this entire story?

In my new book I suggest that the real relevance of gender in this story is to be found not in its role in McClintock's personal socialization, but precisely in the role of gender in the construction of science:

> In a science constructed around the naming of object (nature) as female, and the parallel naming of subject (mind) as male, any scientist who happens to be a woman is confronted with an apriori contradiction in terms. This poses a critical problem of identity: any scientist who is not a man walks a path bounded on one side by inauthenticity and on the other by subversion. Just as surely as inauthenticity is the cost a women suffers by joining men in misogynist *jokes*, so it is, equally, the cost suffered by a woman who identifies with an image of the scientist modeled on the patriarchal husband. Only if she undergoes a radical disidentification from self can she share masculine pleasure in mastering a nature cast in the image of woman as passive, inert, and blind. Her alternative is to attempt a radical redefinition of terms. Nature must be renamed as not female, or, at least, as not an alienated object. By the same token, the mind, if the female scientist is to have one, must be renamed as not necessarily male, and accordingly recast with a more inclusive subjectivity. This is not to say that the male scientist cannot claim similar redefinition (certainly many have done so) but, by contrast to the woman scientist, his identity does not require it. (pp. 174–5).

More generally, I suggest that as long as gender is the axis along which our world is subject to division, women will have more of an incentive to count past two — or perhaps between one and two — than most men will, even though they may still have trouble doing so. That extra incentive derives from the particular costs they bear in a world limited to either unitarity or duality. In the one case, they risk being subsumed, unrepresented, while in the other they face exclusion. In short, I am arguing that because she is not a man, in a world defined for

men, McClintock's survival as a scientist with an intact integrity required that she learn to count beyond two.

It stands to reason that an expansion in our numerical repertoire should enlarge our capacities as scientists, and I have already written at considerable length on the ways in which McClintock's particular vision and practice of science permitted her perceptions and conceptions not available to many of her colleagues, and I will not repeat myself yet again. But in any case, one example will hardly suffice to make the case for a substantive influence of a gendered discourse on science. Nor will two, and indeed, the case for what the subject of gender and science can tell us about science, like the case for what the social studies of science in general can tell us about science, will not be a strong one until a great deal more work has been done on unpacking the relation between language and science. By way of indicating the range of effort that I think is required, let me conclude with a somewhat different example drawn from my current work on the language of evolutionary discourse.

Here, the focus is not so much on the influence of a gendered discourse in analyses of a deanimated nature that has been cast as female, as in analyses of animate nature, inviting more complex and ambivalent forms of projection. In particular, I am thinking of the long history of debate about the role of competition, cooperation and altruism in evolutionary biology, and the ways in which these debates have — and continue to — reflect our cultural romances about male and female nature.

Ever since Darwin, critics have registered protest over the severity of Darwin's picture of nature ('red in tooth and claw'), and the primacy he gave to competition in his description of evolution. At the turn of the century (1902), the Russian anarchist Peter Kropotkin wrote,

> Happily enough, competition is not the rule either in the animal world or in mankind. It is limited among animals to the exceptional periods, and natural selection finds better fields for its activity. Better conditions are created by the elimination of competition by means of mutual aid and mutual support. . . . [N]atural selection continually seeks out the ways precisely for avoiding competition as much as possible. (p. 74).

'Sociability', Kropotkin argued, 'is as much a law of nature as mutual struggle' (p. 5).

The history of the vicissitudes of this generic debate is a long and complex one, and I will touch on only a couple of its key moments. One is a particularly interesting move that came relatively early on and appeared to deal effectively with the kind of objection that Kropotkin

raised. The focus of Darwin's attention, it was said, was not so much on armed combat, dog eat dog overt competition, but on covert competition — the struggle for survival against the drought — struggle, now, 'in a large and metaphoric sense'. In an attempt to avoid its most offensive social implications, competition was redefined to mean the simultaneous reliance on an essential resource in limited supply. In this redefinition, competition is conflated with scarcity, and, at the same time, scarcity comes to be represented as competition — both mathematically and linguistically. That is to say, the consumption of resources is represented in a zero-sum way — my dinner means your starvation, and ultimately, my survival means your extinction.

This relatively more benign formulation of competition in this model — one made eminently reasonable by reference to the economic sphere — appeared to resolve debate. But it also helped to keep people from noticing the fact that it effectively excluded all interactions that cannot be accommodated by a zero sum structure. In particular, any cooperative interaction that could lead to a more efficient use of resources, or to the *de facto* creation of new resources, would conflict with this representation of scarcity. Excluded from our models, such a possibility becomes yet more effectively excluded from our consideration, almost from our imagination — even if not from the range of solutions explored by living organisms. The net effect is that this mathematical and verbal equation of scarcity with competition serves to maintain a conception of organisms — not quite as isolated individuals, but as individuals capable of only one kind of interaction — win or lose. By preempting the field of social dynamics for zero-sum interactions, it obstructs recognition of and attention to the entire range of cooperative or symbiotic phenomena. This tacit restriction amounts to a kind of zero-summing of the world that, I suggest, has had significant consequences for the kind of research that appears to be legitimate, productive, etc. As one example of such an effect, I think of the history of research on cellular symbiosis. Through most of this century, the role of symbiosis in cell evolution has been regarded as uninteresting, implausible, or as E.B. Wilson once wrote, 'too fantastic for mention in polite biological society'. As it happens, it is only quite recently that this subject — in part due to the efforts of such mavericks as Lynn Margulis — has begun to gain legitimacy in the scientific community.

A larger point is that evolutionary theory is in fact rife with concepts that frame the world in zero-sum terms — in a number system of base two. Very briefly, let me mention the rather obvious example of altruism, technically defined to mean behavior that benefits the fitness of another at the cost of one's own fitness. This definition has caused

endless problems for evolutionary biologists, essentially deriving from the fact that, in evolutionary terms, it makes of altruism a logical impossibility. Extraordinary ingenuity has been exercised to resolve the contradiction this fact appears to pose with biological experience, but as yet, a redefinition of the concept — one reflecting a less oppositional relation between self and other — has not been seriously pursued.

Similarly, and closely related, problems can be identified in the entire debate over individual vs. group selection in evolutionary theory. In a recent review of this debate, David Sloan Wilson (1983) observes,

> Group benefit and individual cost together determine the group size at which a character can evolve . . . We therefore arrive at a crucial question: What are the trade-offs between group benefit and individual cost? When is a socially desirable character necessarily costly to the individuals possessing it?
>
> This question is so simple and so fundamental that one might think it would have been carefully examined. On the contrary, it has been almost universally ignored. In almost all discussions of group selection, group benefit is simply assumed to require extreme self-sacrifice . . . This fact is perhaps the largest irony in the history of group selection and its development is well worth tracing (p. 182).

How come, our question is, all those questions about the middle ground between my gain and your loss, between self interest and self sacrifice, between individual cost and group benefit — questions so simple and fundamental — are not being pursued? And does our language — even (or especially), our technical language — help to keep these questions and the wide range of phenomena to which they point out of our vision?

Without question, the story of ideological presuppositions in evolutionary biology is a long and complex one, and I certainly do not mean to hang it all on gender. At the same time, I suggest that that story cannot be properly understood without attention to the ways in which our thinking — or perhaps, I should say, our absence of thought — about male and female nature have crept into our thinking about nature.

One does not need to be familiar with recent developments in feminist theory to notice how well the proclivity toward zero-sum descriptions of relations between self and other conforms to an ideal of masculinity that is deeply embedded in our culture. In fact, one does not need to be familiar with anything but the literature of evolutionary biology itself —perhaps especially the recent literature.

To illustrate the presence and function of a covertly gendered

discourse in these debates, I will read to you — in closing — a brief selection of quotations from the recent literature. Throughout this literature, competition, conflict and individualism are almost invariably associated with maturity, hard realities — what life is really like — in short with truth — while on the other hand, cooperation, harmony, group selection and altruism are associated with a childish desire for comfort and peace, with romanticism — even worse, with sentimentalism, with warmth and security, indeed with motherliness itself.

George Williams, for example, in his epochal 1966 book that is often credited with the vanquishing of group selection, writes:

> There is a rather steady production of books and essays that attempt to show that Nature is, in the long run and on the average, benevolent and acceptable to some unquestionable ethical and moral point of view. By implication, she must be an appropriate guide for devising ethical systems and for judging human behavior. (p. 253)

To explain this rather lamentable shift, Hamilton (1975) suggests:

> Benefit of the species' can thus serve as euphemism and as an escape from inner conflict, permitting us to pay no more emotionally than (for) our childhood acceptance that most forms of life exploit and prey on one another.

By contrast, Ghiselin offers us a view that he claims to be free from any such euphemism, free from all sentimentalism — indeed a view that constitutes something of a challenge, designed to expose the latent sentimentalism residual in even the toughest amongst us. He writes:

> The economy of nature is competitive from beginning to end . . . No hint of genuine charity ameliorates our vision of society, once sentimentalism has been laid aside. What passess for cooperation turns out to be a mixture of opportunism and exploitation . . . Scratch an 'altruist', and watch a 'hypocrite' bleed. (p. 247)

It appears to be with some justification, then, that Dawkins (1982) can write, in his characteristically uncompromising prose:

> 'Genteel' ideas of vague benevolent mutual cooperation are replaced by an expectation of stark, ruthless, opportunistic mutual exploitation . . .
>
> This kind of unsentimental, dog eat dog, language would not have come easily to biologists a few years ago, but nowadays I am glad to say it dominates the textbooks. (pp. 55–6)

Finally, to make it absolutely clear in just what terms the alternative to stark, ruthless exploitation is conceived, Lynn Margulis is described for her work on symbiosis and cell evolution, as 'introducing feminism to Darwinism', and W. Ford Doolittle's recent review is titled, 'Is Nature Really Motherly?'. Doolittle (1981) begins his review with:

> The good thing about this engaging little book by Jim Lovelock is that reading it gives one a warm, comforting feeling about Nature and man's place in it. The bad thing is that this feeling is based on a view of natural selection . . . which is unquestionably false.

My point is not that Lovelock's understanding of natural selection is not wrong — although I don't think it is — or that nature IS motherly — I don't believe this either. In fact I don't even think that mothers are motherly. Rather, it seems to me that what we have here is a kind of projective sentimentalization. Cooperation, mutualism, altruism are projected onto women — endowed with the romance of women's culture — and then readily dismissed as romance and sentimentalism. While on the other hand, competition, conflict, and individualism are associated with the harsh realities of mature men's lives. Given this alternative, between romantic sentimentality and harsh reality, there is no contest. But the fact of the matter is that this framing, this vision of male culture, is equally romantic — it is a romance about a certain kind of masculinity. Real women may or may not be cooperative, mothers may or may not be motherly, Lynn Margulis may or may not be a feminist, men may or may not be warriors. But Nature is oblivious of all our romances, and knows nothing of our gender roles and distinctions. Most probably, the very division that has been set up in theoretical ecology between competition and cooperation is itself unrealistic — loaded in similar ways to the loading of a definition of altruism that excludes the possibility of mutual benefit. A whole world of interactions might be seen between organisms that could not easily fit into a category either of cooperative or competitive. Perhaps, I am suggesting, if we were more attentive to our tendencies to project our own romances onto nature, we might discover new kinds of stories — not yet written in our own scripts. Instead of zero-sum games, or even prisoners' dilemmas, we might discover what we never imagined possible — games that require us to count past two, or between one and two. My favorite example is taken from Ian Hacking's review of Axelrod's *The Evolution of Cooperation* (1984). Hacking cites one of Carol Gilligan's anecdotes, in which a little girl says to her friend, 'Let's play next door neighbors!'

'I want to play pirates', the boy replied.

'O.K.', said the little girl. 'Then you can be the pirate who lives next door'.

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Note

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11 *Changing Minds: Towards Gender Equality in Science?*

Lynda Birke

— Is there gender equality in science?
— Does it matter?

These are the questions that form the basis of most articles in this part of the book. However the various writers address the first question, they all share the assumption that, in science as elsewhere, gender matters. There are thus two tasks that need to be addressed here: first, we have to explain why we think that gender does matter for science, and second, if it matters, then we have to indicate why and how things might be changed. In this article, I want to begin by considering those two questions above, and to argue not only that gender matters but also that we might achieve a better science, a better understanding of the natural world, if we did indeed take more notice of gender. You will no doubt notice a fundamental assumption here, that I am assuming that it is both possible, and desirable, to change science as it is practised today. I am going to take the liberty of making that assumption without arguing for it specifically, because I share with many other scientists a belief that the institution of science can no longer be seen as unequivocally progressive and beneficent. From that belief follows either a profound pessimism, or a belief in the possibility of change. I prefer the latter, and this article is founded upon that belief.

To answer the first of the above questions requires clarifying what we mean by gender inequality: is there equality between women and men in science? In terms of numbers, the answer is a straightforward no, at least at first sight. Men outnumber women in scientific and technological occupations, and more boys than girls study science at school. So in terms of numbers at least, there is no equality.

It isn't, however, only in sheer numbers that gender inequality might be apparent. Even if the numbers were roughly equal, gender inequality might still be apparent in terms of opportunity and access to resources. This raises a question that I was asked to consider in this article: 'do women experience greater difficulties in doing science than men?'. I will argue that they do, although it is necessary to locate this argument in a broader consideration of women's place in our society: science, after all, is only one part of that whole society. In this context, I will consider what sorts of difficulties women might encounter, and some of the explanations offered for this different experience.

The second question is, does it matter? The success of any attempts to change science and women's participation in it depends upon a belief that it does. In the first place it matters if it can be shown that this distribution results from an inequality of opportunity: if so, then there are large numbers of women whose skills and understanding are being denied. There are, perhaps inevitably, always those who would argue that women should not be encouraged into fields in which there is an ever-increasing shortage of jobs for anyone. Furthermore, the evidence quoted from the Butcher Report in Glynis Breakwell's article shows clearly that there is a projected shortage of skilled personnel, not of jobs, in many areas of applied science and technology making this argument less feasible.

The relative scarcity of women matters because it implies that women are not getting the opportunities that they should. But it matters, too, because in a sex-divided society, women generally have rather different skills and experience of life than men, skills and experiences that are being denied to science. If women's perception of nature differs from that of men, then science would surely benefit by that breadth.[1] Gender matters not simply because of the occupational and educational rights of one half of the population, but also because of what that half can bring to the total of human knowledge.

Is There a Problem for Women in Science?

Science, like other professions, poses particular problems for women's careers. Women may encounter overt or covert discrimination, inhibiting access to jobs or promotion. As a result they are more likely to be found in lower ranking jobs or in temporary positions. They may encounter ridicule, or be given less access to necessary equipment. All of these things do occur, even in apparently enlightened institutions. Women in science may be faced with difficulties combining a demand-

ing career with having a family. Most jobs in the early years after a PhD require mobility, moving on after two or three years, a practice which assumes that the person concerned has few or no commitments outside the laboratory. Yet this is possibly the time in life when the woman scientist does have young children at home: if she does devote significant time to them, she is faced with the problem of trying to catch up with the literature — an impossible task in some fields! At the very least, she is liable to be less productive because of other demands on her time.

Anecdotes about discrimination abound. Women have written of discrimination in everything from the access they have to equipment and labs to blank refusals to accept that what they have written is of any value.[2] But anecdotes abound in many fields of human activity, and it is much harder to prove that systematic discrimination exists. Indeed, the difficulty of finding quantitative evidence has led one commentator to infer from statistical evidence that systematic discrimination does not exist in contemporary science.[3] The evidence for this inference is, however, weak; the problems of inferring a null hypothesis from correlative statistics should be well known to any scientist.[4] That such statistics fail to show evidence of discrimination tells us little about the extent of its existence.

Perhaps the most consistent source of discrimination is the belief that women should be primarily responsible for childcare. In turn, childcare is seen to reside in the private domain, far from the world of science. This belief is a more pervasive, and more insidious, form of discrimination than, say, the straightforward belief that women are less capable. It is the source of suggestions that, for example, women should be 'at home with the child',[5] as well as the suggestion that 'women's issues' are not relevant to science. How often do we see male colleagues sneer at symposia such as this on the grounds that women's issues — such as childcare — are irrelevant to the 'more important' themes of science? Science, unfortunately, can't easily be practiced without someone having to wash the socks, and it is still sex discrimination to consider domestic responsibilities as irrelevant to other, less mundane forms of activity.

Discussions such as this commonly note that women are in a minority in science: 'scientists' are typically white, middle-class and male. That women are in a minority is true if you describe what most people mean as a 'scientist'. But it is not necessarily true of all people working in and around science. The functioning of the scientific enterprise depends on laboratory cleaners, technicians and secretaries, just as much as it does on the more prestigious 'scientists'. And, of

course, these supporting roles are more likely to be filled by women. One feminist writer has pointed out how the structure of labour within science mirrors the sexual division of labour within the wider society, in which men tend to occupy higher status, more lucrative jobs, while women tend to occupy 'servicing' occupations — a division which in many ways mirrors the division of labour within the home.[5]

This division of labour has important consequences for women in relation to science. In the first place, it excludes the majority of women from both the process and products of science, contributing to the alienation many women feel from scientific knowledge. Secondly, those women with an interest in science have one of three options. They can (a) opt to work outside the mainstream of science, while maintaining an 'amateur' interest in it; (b) opt to work in one of the supporting occupations comprising scientific work, such as laboratory technician; or (c) opt to enter the bastions of science and become a 'scientist'.[7] But the latter option is open only to a few and still presents women with the problem of domestic responsibility. To take this route, women have, effectively, to run two careers at once. And, with the lack of nursery provision in contemporary Britain, that is no easy option.

It is, perhaps, small wonder that the numbers of women working as scientists or engineers is relatively low. Discrimination in its various forms combines with the practical difficulties of the scientific career path to pose a heavy burden on women. Science, the archetypal problem-solving activity, thus poses problems for women. These problems, however, do not arise solely along the postgraduate path to a scientific career: the rot sets in much earlier. Science is more likely to be chosen for study at school by boys than girls, and more boys take public examinations in science subjects. Indeed, while the problems faced by women in their careers no doubt do contribute to women's exclusion from science, they are, by and large, not problems that are unique to science. Discrimination occurs in many occupations, and the sexual division of labour is pervasive. But what is significant for science is its dependence upon the selection, in the early teenage years, of particular school subjects. It is this which is the root of women's exclusion from science.

Explaining the Problem

If women tend to become excluded from science from their schooldays on, what is the reason? One answer might be to suggest that there are no institutional barriers, and that it depends primarily on individual

aptitudes and willingness to work. Thus, those women who do succeed do so because they alone are clever or assertive enough. Those who do not clearly do not have sufficient motivation or ability. Obviously, ability and motivation are necessary to succeed in any career; they are not, however, sufficient to explain the wide disparity between men and women in science. This kind of explanation both ignores the various reasons why individual women may or may not succeed (such as social class, the existence of patronage, mobility, etc.) and locates the problem firmly within individuals who are alone to blame for their successes or failures in life.

The emphasis on the individual and the priority of her/his particular abilities is embedded in Western thought, giving rise to a variety of explanations of human social structures. One form of argument based on the primacy of the individual is to assert that particular characteristics have a specifically biological basis; that is, that they are rooted in the unique biology of that individual. Thus, in order to explain women's scarcity in science, biological differences between the sexes have been invoked. One example of this is the suggestion that visuospatial skills are essential for the abstract reasoning on which science is based, and that such skills are linked to biological bases. (One example is the suggestion that the relevant skills are determined by a recessive gene on the X chromosome.)[9]

But is there any evidence of such biological determination? Despite a number of attempts to do so, there has not been marked success in demonstrating that gender differences in scientific ability are linked to any biological substrate. It is not my concern here to make the detailed case against biological determinism, as that has been done elsewhere,[10] but I would make two relevant points. First, simple biological variables, such as genes, hormone levels, or whatever, are unlikely to have any straightforward relationship to complex human abilities. Moreover, even if such biological variables were correlated with spatial ability,[11] science consists in far more than that. To succeed in science requires far more than the ability to solve a few spatial puzzles.

The second point is that, even if biological determination could be proven, it does not explain why discrimination should exist. Indeed, if women could be shown to have lesser ability on average for some biological reason, that might even be an argument in favour of compensatory educational practice to give them more chance. In practice, however, scientific education still tends to use methods and examples which favour the experience of boys rather than girls.[12]

Biology, moreover, cannot completely explain the differential motivation of even very able girls and boys to do science. True, anyone

with greater ability is more likely to have greater motivation for that subject, but that alone does not explain the extent to which girls and boys differ in the way that they view science. Girls, for example, are more likely to view nature in terms of relationships and of its relevance to human needs, while boys are more likely to view science in abstract terms, for its own sake.[13] This difference in perspective is one which will inevitably affect motivation for the kind of science that is currently taught in Britain, and which is, on the whole, a science taught extensively in rather abstract terms. Girls tend to become alienated from this other-worldly, abstract image of science, and to see it as possibly less relevant to their everyday lives.

This difference in motivation and perspective does not seem to correlate well with ability, in that even scientifically very able girls tend to share this perspective. But before reverting to a biological hypothesis to explain such a view, it is worth remembering that many boys share it too. While it is currently fashionable to invoke biological explanations for various complex social phenomena, from male philandery, to indoctrinability, and to monetarism,[14] such 'explanations' actually tell us little. It is not easy to see how a tendency to view the natural world in a particular way can be causally related to the action of particular genes. Genes make proteins, not world views.

A more plausible hypothesis concerning the origin of these differing perspectives is the view that such differences derive essentially from the sexually differentiated processes of interaction between the child and its mother. Child-rearing practices in the West are carried out almost entirely by women and, it is argued, have considerable influence upon the attributes of both genders.[15] While a primary task for all children is to develop autonomy, away from the mother, this presents different problems for boys and for girls. For girls, the link to the mother remains through identification of gender similarity: for boys, by contrast, gender dissimilarity breaks the link. It is these processes that are said to lead to women's greater sense of connectedness and relationships, while boys learn autonomy, and separation.[16] If these qualities are, as has been suggested, the roots of objectivity, and abstract reasoning, then boys are more likely to seek the pursuit of such things in later life. And what else is science but the quintessential pursuit of objectivity?

These ideas are important because they locate the origins of women's exclusion from science in early development, in the cultural patterns by which gender identity is learnt within the family. The problems facing women in relation to science, then, are not relatively trivial ones such as discrimination, but lie deep in the sexual divisions of society itself. As long as only women are responsible for childrearing,

girls will grow up with a greater sense of relationships and embeddedness than boys, and will thus be more likely to be alienated from the abstractness of science. An immediate response to this kind of theorizing is, however, that it is profoundly pessimistic. Like theories rooted in biological determinism, it carries little hope of change, at least in the foreseeable future. The role of women as primary caregivers within the family seems likely to remain for some time to come.

I do not think that such pessimism is necessarily warranted, however, as I shall argue a little later. For now, the most important point to make is that, while girls *perceive* science as less relevant to their lives and to their needs as social beings, then they are less likely to choose it. However ill-founded it may be, our culture shares a common image of science that it is somehow remote, abstract, and requires a degree of separation of the human observer from the natural world — the true pursuit of objectivity. If girls do tend to see themselves as more embedded in relationships with both other people and with nature, then they are not going to find this image of science either convincing or appealing.

That image of science is also lacking in appeal to girls for another important reason: it is fundamentally masculine, standing in opposition to a girl's sense of emerging femininity. Whatever else they might be, science and technology have inherently 'masculine' images in our culture. In part, this arises for the obvious reason that it is largely men who do them. But the masculinity of science arises in other ways. First, it arises because objectivity is associated with masculinity in our culture; to be subjective, by contrast, is to be seen as more feminine. Secondly, science is competitive, a trait also culturally associated with masculinity. Sally Gearhart, writing about objectivity in science commented that

> 'To prove' ... seems to replace 'to know' in Western science, thus altering the task of *discovery* to one of *justification*, and thus revealing as well a self-serving component of the epistemology. The vast and proliferating desire of scientists to show knowledge to others obscures whatever noble motive — curiosity, the love of learning, — might have inspired them early in the annals of science or in their personal history ... the self-aggrandizement inherent in the drive of science to 'prove' seems a far cry from even the traditionally highly touted function of science: to discover the laws of nature.[17]

This self-serving competitiveness seems only to increase in the present air of 'publish or perish'. Given that women tend to be more co-operative in personal style than men, and to abjure such levels of

competition,[18] this face of science can hardly attract women.

Thirdly, in some areas of science, it is masculine precisely because of the ways in which it defines the attributes of women and men. Feminist critics have often pointed to the myriad ways in which research in certain areas of biology and psychology is shot through with assumptions about the essential nature of women, assumptions which serve to reinforce the marginality of women both within and without scientific work. Various biological theories proclaim the biological determination, in one way or another, of such feminine attributes as passivity, coyness, nurturance and facility at typing, while similar biological theories espouse a belief in the underlying bases of male aggression, assertiveness and objectivity.[19] Insofar as these stereotypes help to reinforce the oppression of women by implying that gender roles are forever fixed, then the science that perpetuates them can be said to act in male interests. In that sense, even its content becomes masculine.

If science and technology are seen as thoroughly masculine, then we can hardly be surprised if girls — at a time in their lives when gender does matter — sometimes shy away from them. Science's masculinity comes into direct conflict with their self-concept of femininity and women's role. It might be objected that this does not really matter, that those girls who are particularly worried about self-definitions of femininity would not make the best scientists anyway. Besides, what is wrong with science being masculine?

Apart from the fact that that image of masculinity necessarily excludes the experiences and values of half of the human race, it has been argued that the very masculinity of science was fundamental to the drive to produce the atomic bomb.[20] Individual competitiveness and a belief in the abstract power of man (sic) to conquer nature were more in evidence in its development than any consideration of the consequent destruction of life. If these traits are indeed symptomatic of science's inherent masculinity, then that is very good reason for wanting to change it.

Changing Minds: Removing the Inequalities

How the penalties facing women in science might be overcome obviously depends in part upon the explanation offered for women's exclusion. If, for instance, that exclusion rests upon some feature of women's versus men's biology, then there is, presumably, little that can be done about it. Some policy of affirmative action might conceivably redress the balance somewhat, but the biologically determined abilities

would put constraints on what might individually be achieved.[21]

In what follows, however, I am going to assume that there are no obvious biological constraints on women's talents — for none have been proven — but that the constraints lie in the social subordination of women. At least in theory, that assumption gives scope for change. There are three areas that I want to consider. First, what scope is there for 'institutional' change? That is, how much can be achieved by, say, deliberate policies to create opportunities within science for women? Secondly, given that women face greater problems in their careers owing to their domestic responsibilities, to what extent can the organization of science be changed to allow greater flexibility for women working within it?

Those two possibilities rest on attempts to open up opportunities for women, to make scientific work more attractive to those having the initial interest in science. But many women do not have that initial interest, and are alienated from science; for these, creating new opportunities or changing working conditions will have little impact. The third possibility to consider, then, is whether science itself might be changed, to make it less alienating and thus more attractive to those women (and men) who find the assumptions and practice of contemporary science distasteful. Here, I will return to the question of whether or not science might be thought of as 'masculine' and if so, whether a change in that image is desirable.

What scope is there for institutional change? 1984 was designated WISE year — women into science and engineering — and a great many educational institutions and employing industries attempted some form of activity to encourage more women into these professions. There have also been attempts to create more opportunities at school, such as the Manchester-based GIST project (Girls into Science and Technology). Teachers can, for example, attempt to reorganize classrooms, so that girls are given more opportunity for 'hands-on' experience of practical science; they can attempt to use illustrative examples that either appeal more directly to girls (domestic examples are often used) or that are relatively neutral in their connotations of gender. Girls are simply less interested in examples based on rockets and motorbikes, and are likely to consider these pretty irrelevant! Schools can also pursue deliberate policies of affirmative action, to the extent that a balanced ratio of women to men is attained among science staff. This action is based on the belief that female science teachers can act as 'role models' which will encourage girls to study science themselves. (To what extent this happens is hard to say: when I was a schoolteacher a few years ago, discussing with girls the desirability or otherwise of doing

science, they concluded: 'but it's different for you, Miss'. I never did discover how!) Science can also be taught in ways that emphasize its social and economic importance, and reduce the significance of its abstract, depersonalized, side. The achievements of women scientists and engineers throughout history can be emphasized.[22]

All of these approaches have been tried, with varying results. The basic problem with such strategies in practice is, of course, that they tend to become rather piecemeal, having to rely on the goodwill of individual teachers and schools. Meanwhile, many other teachers continue to make sexist assumptions about the scientific abilities of girls and boys and to teach them accordingly. This kind of approach is nevertheless important if we are to encourage more girls to do science, and as more do do it, then it may become less of a male preserve. But it is not enough on its own. No attempts to encourage girls can overcome the problems resulting, for instance, from women's responsibility for the home.

The suggestion has been made that the organization of scientific work does not take into account the sexual division of labour, with the implication that if it did, it might become more accessible to women.[23] Certainly, women scientists often do find it difficult to combine their work with domestic responsibilities and would welcome moves to make that combination easier. Scientific work, too, would probably benefit from becoming more flexible, with greater opportunity to pursue other activities — for both women and men. Science does rely heavily on individual expertise, so practices such as job-sharing are less readily adapted to it.[24] But there may well be situations in which such an arrangement might be suitable, and even advantageous, bringing the benefits of two trained minds to a scientific problem, rather than one. Less emphasis might be placed on mobility in a scientist's early career, particularly for married women: it is taken for granted that mobility is a good thing, but other things need to be weighed against these putative advantages. Indeed, a high degree of mobility can also be disruptive, particularly in those areas of work involving long-term experiments.

Various means might be tried to achieve greater flexibility of this kind, although it is symptomatic of the organization of science that they have rarely, if ever, been attempted on any significant scale. To a large extent, too, such efforts are likely not to challenge the sexual division of labour, but to perpetuate it. That is, while greater flexibility would work to women's interests in allowing them greater freedom to combine career and family, this freedom still rests on their domestic responsibility.

While women continue to be primarily responsible for domestic

arrangements, and while their male colleagues are not, women are more heavily penalized. In a career that places great value on individual productivity, those penalties can be high indeed.

To succeed in science requires that a scientist can transfer at least some domestic responsibility and labour onto other people. For the majority of male scientists, this is likely to be the wife. Women scientists face bigger problems. As one feminist writer observed, 'only the most exceptional women from highly privileged class backgrounds — who can, therefore, transfer their domestic labour to other women — are able to get into science'[25] Women can do this — though often guiltily — or they can try to combine both work and family. With such difficult tasks it is small wonder that some women do not feel that it is worth the effort.

At the stage at which they are considering career options and subject choices, girls are usually cognizant of the demands of a family versus profession, and recognize that there will be great strain on their own lives if they try to combine the two. It is at least possible that more girls would accept entry to the professions as a realistic goal if they did not feel that they would inevitably have to face such a dilemma. The problem, of course, lies in trying to change not just science, but society more generally, so that gender inequalities in both paid work and domestic labour are minimized. That goal, however, is far from realization.

The third approach is somewhat more speculative, and that is to change the content and methods of science: if science is somehow masculine, can that masculinity be changed to make it more attractive to women? This is the theme of a number of recent papers dealing with the notion of creating a 'feminist science'.[26] By this, the writers mean somewhat different things, but all are united in a belief that the current masculinity of science contributes to women's exclusion from it, and that science can and should be changed. This type of approach, akin to the notion of creating a 'socialist' science that is espoused by the radical science movement, often rouses opposition on the grounds that it is tantamount to 'interference' in the rights of scientists to pursue whatever line of enquiry they choose. We cannot predict, it is pointed out, the direction of knowledge and thus should not try to interfere with its progress.

This opposition is naive, however, since we already do interfere in science. The direction of science in Britain, as elsewhere, is largely determined by government policy and expenditure (thus, the greater part of current British R. and D. expenditure is defence-related). Moreover, there are some approaches or areas of work that are

proscribed or controlled. We do not accept experimentation (except under certain carefully defined conditions) on fellow human beings; we impose restrictions upon the experiments that can be done in genetic engineering, or that can be done on other species of animal. Further, most research is product-oriented, not all of which is geared towards the production of socially necessary or useful technology. This is 'interfered' with in the sense that what is at stake is not the pursuit of knowledge for its own sake, but the pursuit of greater company profits. The belief that scientists have an inalienable right to do whatever they want is quite simply a myth.

So I would argue that it is perfectly feasible to talk of changing the content of science if we so wish. Among other things, this would require recognizing science as a social activity, with responsibilities towards the larger society, rather than viewing it in terms of the rights of the individual scientist or company to pursue whatever it thinks fit. Unfortunately, change of this nature is rather dramatic, and not immediately achievable in the face of Western emphasis on the rights of the individual and the pursuit of profit.

More realistically, however, we might consider changing the ways in which we teach and think about our relationship with nature, to make it more acceptable and less alienating — to reintroduce, if you like, the human face of science. Being a biologist, the examples on which I will draw are to do with biology; I will leave it to the physicists and chemists to delineate any potential for change in those subjects.[27] I want to consider two approaches. The first is to place less emphasis on the impersonal, reductionistic kind of science that is still the backbone of school and college biology. In this way, the biology might be made less alienating for those women who begin to study it. Secondly, I want to return to the comments I made earlier, about biological theories of women and gender, and to argue that, if we were to change the ways that we think about the acquisition of gender in relation to biology, then we might reduce the sense of separation from the object of study that leads to the cold hard-headed objectivity which many women find alien. This is not going to be an argument against objectivity *per se*, but an argument in favour of greater integration and connectedness in our views of nature.

That much of modern science is highly mechanistic and reductionistic has often been noted.[28] It is a way of looking at the world that many people, but particularly many women, find difficult to understand and often find abhorrent. It has also been successful, enabling humanity to exploit the environment and to use human creativity to produce innovative forms of technology, yet it is precisely this sense of science as

enabling exploitation which many find objectionable, and the past few decades have seen much greater awareness that science is not necessarily synonymous with progress. More and more, popular emphasis is turning away from the reductionist emphasis on reducing nature to its smallest bits, and towards an emphasis on seeing nature in terms of integrated wholes. This kind of shift is most noticeable in the 'green' or ecology movements, but is also evident in feminism, which draws attention to the parallels between the exploitation of the (female) earth and that of women.[29] The emphasis of these social movements on holism and integration should not be ignored: it lies in direct opposition to reductionist science and provides an attractive alternative vision of nature to those put off by the exploitation that they perceive as contemporary science.

There are, of course, some areas of science that are less reductionist, and some that are becoming so, although the bulk of science still adheres to reductionism, both as an underlying philosophy and as methodology.[30] Indeed, it might be argued that, because reductionism has been central to twentieth century science, it is synonymous with science and it would be nonsense to talk of alternatives. Despite its obvious successes, however, there is much about the complexity of the natural world that reductionism cannot explain and so biologists are necessarily turning to more complex interpretations of nature.

Molecular biology, for instance, has long been one of the most reductionist areas of biology, dominated by the molecular version of the central dogma (according to which DNA makes RNA makes protein). For a long time, any scientist who worked outside the prevailing ethos was likely to be ignored.[31] But that dominance is now less marked, and there is increasing emphasis on the interconnectedness of cellular and molecular events: DNA is no longer the 'master molecule' but seen as part of a more complex system. Similarly, ecology, originally the least reductionist of all the biological sciences, became increasingly reductionist during the 1960s, apparently obsessed with ideas of competition and battles for survival.[32] While much of the battle-ground rhetoric continues into the 1980s,[33] there is simultaneously a greater concern with more holistic approaches.[34]

I think that at least some areas of biology are showing signs of change, and more people are becoming aware of the need to understand nature as an integrated whole. There are, too, specific attempts in some areas of biology to try to create a less reductionist approach to the problems studied.[35] But to change the image of science so that its appeal is broadened will require far greater changes in the underlying philosophy than a few pockets of resistance. If girls (and some boys) are

opting out of science at school because they want to see nature in terms of relationships and connectedness, then we have to change the image of science that is conveyed in schools. There is, of course, a degree of realism in their avoidance of science, in that the vast majority of scientists in Britain are employed in highly exploitative and reductionist work. That, however, is no reason to go on teaching the same assumptions to the next generation.

The wholeness of nature, however, also includes the observing human, and to observe it in this way requires acceptance of the fact that it is simply not possible to stand outside nature in pursuit of an ideal objectivity. I referred earlier to the hypothesis that 'objectivity' has become masculine in Western culture through the greater sense of separation and autonomy inculcated in boys through gendered patterns of child-rearing. I have no dispute with that idea, but want to argue that this separation also implies a separation from the biological self that fits in well with dominant conceptions of the significance of human biology. It also has implications for the ways in which men and women approach science.

A number of theories of gender development either leave human biology out altogether, adopting a social conditioning stance, or assume biology to be additive and primary.[36] That is, biological factors are seen to provide the raw material, the base, onto which the cultural superstructure is added. This additive model is implicit in the idea that, for instance, we can partition out 'intelligence' into heritable and learnt components.[37] Similarly, in some theories of gender development, biology determines the initial division by sex, and cultural learning then occurs in accordance with that biological base. The biology in such a model is primary, not only in the ontological sense, but also ontogenetically. A person's biology is thus assumed not to have any influence upon their sense of gender after that primary period.[38]

A belief in the primacy of biology in our development means that there is an implicit belief that we can leave it behind, somehow forever fixed — which, coupled with the proposed greater sense of separation for boys because of child-rearing practices, implies a greater sense of separation from the biological self. Women, on the other hand, are often described as being more in touch with their biological selves, seeing them as more connected with the larger biological environment.[39] In relation to biology, at least, that sense of separation from the biological self contributes to the masculine belief that we *can* stand outside nature, passively observing. Women are often less convinced that we can do so.

The additive model is not the only way, however, of describing

development, and 'interactive' models are often proposed in order to circumvent the problems posed by additive ones.[40] In similar vein, we might view gender development in interactive terms. I do not, however, mean this in terms of a brief interaction leading to a fixed sense of gender, but as a continuing process, in which one's biology and cultural environment are in constant interplay, leading to a dynamic, rather than static, sense of gender.[41] In traditional theories of gender development, gender is fixed at an early age; thus, the obvious biological component that can influence that identity is external anatomy and the child's recognition of it. What I would suggest, instead, is that for adult women (say) the continuing biological experiences of, for instance, menstruation and childbirth will become part of their sense of gender, both incorporated into it and in turn being affected by it. This sense of gender development thus allows that *adult* biology can be influential to our self-concepts of gender, and the 'biology' is not simply the presence of particular anatomy at birth.

If a more interactive and dynamic view of the development of gender were widely accepted, rather than the now-dominant additive model, then the belief that humans (and particularly men) can stand apart from the biological world and observe it dispassionately would be less credible. It is only while we believe that our biology has been fixed since birth (or earlier) that such a belief in separation from biology becomes tenable.

Young girls are often drawn initially to biology because it ostensibly involves the study of living things, the nature to which they feel connected; but many are subsequently put off because at higher levels of study biology involves — quite literally — cutting nature into smaller and smaller bits. Boys are less likely to be disturbed by the sense of connection because their culture has taught them to separate themselves off from their biological reality and to deny its transformability. And if the connection of the natural world to oneself is hard for some to see in biology, then how much harder is it in the other natural sciences?

The profoundly masculine image of science will have to be changed if more women are to be attracted to science, and I have broadly outlined two kinds of changes that might occur. These involve large-scale shifts in our perceptions and underlying assumptions — paradigm shifts, if you will. Much of this analysis has been highly speculative, considering ways in which our image of science (but particularly biology) might be changed. Those who believe that we cannot change the premises and philosophy of science and ought not to tinker with its pursuit of knowledge will probably think my suggestions absurd. What I have written, however, rests on a belief in both the possibility of change

and also its desirability. There are many people now — scientists and non-scientists alike — who have grave doubts about the present direction of science. Unless we are to throw up our hands in despair, then our only choice is to try to change it. If we had a different kind of science, one which emphasized respect for, and cooperation with, the nature it studies, then more girls or women might be drawn into it. But, in a sense, that is of relatively minor importance. Learning a sense of our connectedness with the rest of the universe, and a science to go with it, rather than learning a science of exploitation and destruction, is surely an important lesson. And that applies to all of us, whatever our gender.

Notes

1 That women's psychology and outlook does differ from men's has often been noted, but see particularly GILLIGAN, C. (1982) *In A Different Voice*, Cambridge, MA, Harvard University Press.

2 See, for instance, ARDITTI, R. (1979) 'Feminism and science' in ARDITTI, R., BRENNAN, P. and CAVRAK, S., (Eds.) *Science and Liberation*, Boston, MA, South End Press; WEISSTEIN, N. (1979) 'Adventures of a woman in science' in HUBBARD, R., HENIFIN, M.S. and FRIED, B., (Eds.) *Women Look at Biology Looking at Women*, Cambridge, MA, Schenkman; and KELLER, E.F. (1982) 'Feminism and science', *Signs*, 7, 3, pp. 589–602.

3 COLE, J. (1979) *Fair Science: Women in the Scientific Community*, New York, and London, Macmillan.

4 For other criticisms of Cole's work see GAYE TUCHMAN's review of the book in *Social Policy*, May/June 1980, pp. 59–64.

5 See, for example, ARDITTI, R. (1979) *op. cit.*

6 For further discussion of this point see *ibid.*, and ROSE, H. (1982) 'Making science feminist' in: WHITELEGG, E. *et al.*, (Eds.) *The Changing Experience of Women*, Oxford, Martin Robertson.

7 I am referring here to choices in relation to more prestigious research science; women can, and often do, choose a scientific career in the form of schoolteaching.

8 The significance of this priority within liberal traditions for women and feminism is discussed by JAGGER, A. (1983) *Feminist Politics and Human Nature*, Brighton, Harvester.

9 For example, see GRAY, J.A. (1981) 'A biological basis for the sex differences in achievement in science?' in KELLY, A. (Ed.) *The Missing Half*, Manchester, Manchester University Press.

10 See, for example, BRIGHTON WOMEN AND SCIENCE GROUP (1980) *Alice Through the Microscope: The Power of Science Over Women's Lives*, London, Virago; SAYERS, J. (1982) *Biological Politics*, London, Tavistock; THE DIALECTICS OF BIOLOGY GROUP, (1982) *Against Biological Determinism*,

London, Allison and Busby. Birke, L. and Silvertown, J. (1984) (Eds.) *More Than the Parts: Biology and Politics*, London, Pluto Press; and Rose, S., Lewontin, R. and Kamin, L. (1984) *Not in Our Genes: Biology, Ideology and Human Nature*, Harmondsworth, Penguin.

11 Males only score better than females on some tests, and not on others. See Maccoby, E.E. and Jacklin, C.N. (1976) *The Psychology of Sex Differences*, Oxford, Oxford University Press. Also see Sabaga, E. and Griffiths, D. (1981) 'Biological inevitabilities or political choices? The future for girls in science' in Kelly, A. (Ed.) *op. cit.*

12 See various contributors to Kelly, A. (Ed.) (1981) *op. cit.*

13 See discussion in Kelly, A. 'Retrieving the missing half' in Kelly, A. (Ed.) (1981) *op. cit.*

14 For critiques of such sociobiology, see BSSRS Sociobiology Group (1984) 'Human sociobiology' in Birke, L. and Silvertown, J. (Eds.) *op. cit.*; and Rose, S., Lewontin, R. and Kamin, L. (1984) *op. cit.*

15 See, for example Chodorow, N. (1978) *The Reproduction of Mothering*, Berkeley, CA, University of California Press.

16 See Keller, E.F. (1983) 'Women, science and popular mythology' in Rothschild, J. (Ed.) *Machina ex Dea*, New York and Oxford, Pergamon Press; and Keller, E.F. (1983) 'Gender and science' in Harding, S. and Hintikka, M.B. (Eds.) *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology and Philosophy of Science*, Dordrecht, Reidel.

17 Gearhart, S. (1983) 'An end to technology: A modest proposal' in Rothschild, J. (Ed.) *op. cit.*, pp. 174–5.

18 See, for example, Lowe, M. (1984) 'Cooperation and competition in science', *International Journal of Women's Studies*, 7, pp. 362–7.

19 See footnote 10 above.

20 Easlea, B. (1983) *Fathering the Unthinkable: Masculinity, Scientists and the Nuclear Arms Race*, London, Pluto Press.

21 E.O. Wilson considers how we might organize society in the knowledge of biological constraints upon gender, and suggests that, whatever we did, men would still predominate in science. See Wilson, E.O. (1979) *On Human Nature*, New York, Bantam, pp. 137–9.

22 See, for example, Mozans, H.J. (1974) *Woman in Science*, Boston, MA, MIT Press; Rossiter, M.W. (1980), 'Women's work in science: 1880–1910', *ISIS*, 71, pp. 381–98; Stanley, A. (1983) 'Women hold up two-thirds of the sky: Notes for a revised history of technology' in Rothschild, J. (Ed.) *op. cit.*; and Alic, M. (1985) *Hypatia's Heritage: A History of Women in Science*, London, The Women's Press.

23 See footnote 6 above.

24 This is less true in some areas, such as computing.

25 Rose, H. (1982) *op. cit.*, pp. 366–7.

26 See footnotes 6 and 16 above. Also see Fee, E. (1983) 'Women's nature and scientific objectivity' in Lowe, M. and Hubbard, R. (Eds.) *Woman's Nature:*

Rationalizations of Inequality, Oxford, Pergamon Press. BEHER, R. (1984) *Science and Gender: A Critique of Biology and its Theories on Women*, New York and Oxford, Pergamon Press; and BIRKE, L. (1986) *Women, Feminism, and Biology*, Brighton, Harvester.

27 Though some writers have pointed to quantum physics as indicating analogous change in physics.

28 See footnote 10. Also see MERCHANT, C. (1982) *The Death of Nature: Women, Ecology and the Scientific Revolution*, London, Wildwood.

29 *Ibid.*; also see various contributors to CALDECOTT, L. and LELAND, S. (Eds.) (1983) *Reclaim the Earth: Women Speak Out for Life on Earth*, London, The Women's Press.

30 See, PEACOCKE, A. (Ed.) (1985) *Reductionism in Academic Disciplines*, Guildford, SRHE and NFER-Nelson.

31 This was the case with, for instance, Barbara McClintock's work on maize genetics. See KELLER, E.F. (1983) *A Feeling for the Organism: The Life and Work of Barbara McClintock*, New York, W.E. Freeman.

32 SILVERTOWN, J. (1984) 'Ecology, interspecific competition and the struggle for existence' in BIRKE, L. and SILVERTOWN, J. (Eds.) *op. cit.*

33 For a good example of this see the one cited by GROSS, M. and AVERILL, M.B. (1983) 'Evolution and patriarchal myths of scarcity and competition' in HARDING, and HINTIKKA, M.B. (Eds.) *op. cit.*, p. 86.

34 GROSS, M. and AVERILL, M.B. (1983) *op. cit.* discuss this in relation to feminist ideas.

35 For example, the work of the Dialectics of Biology Group (1982), *op. cit.*; and *Against Biological Determinism* (1982) *Towards A Liberatory Biology*, London, Allison and Busby.

36 A brief account of the major theories of gender development is given in KESSLER, S. and MCKENNA, W. (1982) 'Developmental aspects of gender' in WHITELEGG, E. *et al.*, (Eds.) *op. cit.*

37 For a critique of this, see KAMIN, L. (1974) *Science, Politics and I.Q.*, Potomac, MD., Erlbaum.

38 The extent to which 'biology' is involved in major theories of gender development varies, but is largely concerned with external genital anatomy, which determines the initial division into two sexes. 'Gender' is then assumed to be constructed in accordance with this initial division.

39 In part, this is due to the association in recent Western thought between women and nature (as opposed to men and culture). The nature/culture dichotomy is discussed in MERCHANT, C. (1982) *op. cit.*, and by BROWN, P. and JORDANOVA, L. (1982) 'Oppressive dichotomies: The nature/culture debate' in WHITELEGG, E. *et al.*, (Eds.) *op. cit.*

40 These commonly assume, however, that the factors have interacted in the past to produce a (fixed) present gender identity. The latter becomes a dependent variable. For discussion of this, see BUSS, A. (1979) *A Dialectical Psychology*, New York, Irvington, pp. 161–8. Also see BIRKE, L. (1986) *op. cit.*, especially chapter 5.

41 *Ibid.* One controversial consequence of this is that a male-to-female transsexual would have a different sense of gender identity from a biological woman, since adult gender identity becomes influenced by the biological experience through which the person has been.

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Carl Grant, University of Wisconsin-Madison and Christine Sleeter, University of Wisconsin-Parkside

The issue of women and science has gradually assumed prominence over the past decade. Concern for the underachievement of girls and women in science education and in scientific and technological employment has been orchestrated in Britain by three main groups: science educators, feminists and science-based industry. The perspectives of each group, their definitions of 'the problem', the explanations advanced for it and the strategies implied for dealing with it, differ.

It was against this background that the Section X (General) Committee of the British Association decided in 1983 that the theme for the Section programme in 1985 would be 'Women in Science'. This volume contains the papers presented in that programme, only marginally modified for publication.

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